CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK No. 12

1913

PUBLISHED BY THE INSTITUTION
WASHINGTON, U. S. A.

WASHINGTON, D. C.
PRESS OF GIBSON BROTHERS, INC.

OFFICERS FOR THE YEAR 1914.

President of the Institution.

Trustees.

Executive Committee.

Finance Committee.

Auditing Committee.

* Ex-officio member.

LIST OF PRESENT AND FORMER TRUSTEES.

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ORGANIZATION, PLAN, AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION.

PUBLIC NO. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

Sec. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

Sec. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

Sec. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

Sec. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

Sec. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

Sec. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

TWELFTH MEETING OF THE BOARD OF TRUSTEES

ABSTRACT OF MINUTES OF TWELFTH MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington, in the Board Room of the Administration Building, on Friday, December 12, 1913, and was called to order at 10 o'clock a. m. by the vice-chairman, Mr. Root.

Upon roll-call by the secretary, the following Trustees responded: Robert S. Brookings, Cleveland H. Dodge, Simon Flexner, Henry L. Higginson, Charles L. Hutchinson, S. Weir Mitchell, Andrew J. Montague, William W. Morrow, Wm. Barclay Parsons, Henry S. Pritchett, Elihu Root, Martin A. Ryerson, Charles D. Walcott, Henry P. Walcott, William H. Welch, George W. Wickersham, Robert S. Woodward.

Upon assuming the chair, Mr. Root stated that no one could hope to render to the Institution service of such great value as Dr. Billings rendered. "His sturdy independence, absolutely frank and fearless expression of honest opinion, combined with wide and catholic learning, during the formative periods of this Institution were of a value that it is impossible to estimate."

The minutes of the eleventh meeting were approved as printed and submitted to members of the Board of Trustees.

The reports of the President, the Executive Committee, the auditor, the Finance Committee, the Auditing Committee, directors of departments, and grantees of the Institution were presented and considered.

The following appropriations for the year 1914 were authorized:

Administration	$50,000
Publication	60,000
Division of Publications	10,000
Departments of Research	689,645
Anthropology	20,000
Embryology	26,900
Minor Grants	94,900
Index Medicus	12,500
Insurance Fund	25,000
Reserve Fund	250,000
Exhibit at Panama-Pacific International Exposition	10,000
	1,248,945

Mr. Henry White was elected to fill a vacancy in the Board caused by the death of Dr. Billings. Mr. Root was elected chairman of the Board for the unexpired term of Dr. Billings, and Mr. C. D.

Walcott was elected vice-chairman of the Board for the unexpired term of Mr. Root.

Dr. Simon Flexner was elected a member of the Executive Committee for the unexpired term of Mr. Root, who (by reason of his election as chairman of the Board) succeeded to the ex-officio vacancy in the Committee caused by the death of Dr. Billings.

The Board adjourned at $12^h\ 45^m$ p. m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1913

JOHN SHAW BILLINGS
1838-1913

REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, I have the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1913, along with recommendations of appropriations for the ensuing year and with sundry suggestions concerning other matters of general or special interest.

This report is the twelfth annual report of the Institution and is presented under the following principal heads:

1. Salient events of the year.
2. Outline of researches of the year.
3. Financial records.
4. Publications.
5. Proposals for budget for 1914 and other recommendations.

SALIENT EVENTS OF THE YEAR.

Necrology.

The history of an institution may be derived essentially from the aggregate of the biographies of participating individuals; and in proportion as the number of such individuals is large the complexity of this aggregate presents difficulties of interpretation and obstacles in the way of a just appreciation of even conspicuous merits. Thus it happens that the history of the Carnegie Institution of Washington is already a highly complex affair, to which not less than two thousand individuals have contributed directly, in one way or another, while the number of those who have contributed indirectly must be at least ten times as great. Among this considerable list of contributors to the development of the Institution, death has fallen naturally most heavily on members of the Board of Trustees, of whom thirteen from a total of thirty-nine are to be numbered as deceased before the Institution has fully emerged from the formative period of its existence. Twelve of these colleagues died during the first decade of this period. Their names make a roll of distinction quite irrespective of their connection with the Institution. They need only to be designated alphabetically to recall the services they rendered in the progress of our times: Alexander Agassiz, William E. Dodge, Daniel C. Gilman, John Hay, Abram S. Hewitt, Ethan A. Hitchcock, Henry Hitchcock, William

Wirt Howe, Samuel P. Langley, William Lindsay, D. O. Mills, Carroll D. Wright. And now to this roll of our distinguished dead from the Board of Trustees must be added the name of John Shaw Billings, who died in New York City, March 11, 1913, aged seventy-four years and eleven months.

Doctor Billings, as he was familiarly known to us, was one of the original incorporators of the Institution and one of the most active and effective participants in its organization and growth. He served as Vice-Chairman of the Board of Trustees from the date of the first incorporation in January, 1902, until the death of the first Chairman, Abram S. Hewitt; as Chairman of the Board since December, 1903; and as a member of the Executive Committee continuously from the date of its organization in January, 1902, to February, 1913. At the end of the last meeting of the Executive Committee he attended, February 20, 1913, he told Doctor Mitchell and me of a sense of weariness and of his anticipation of need of surgical treatment in the near future. Of this need he spoke with accustomed fortitude, but with apprehension that he might not withstand the resulting shock. His prognosis proved characteristically accurate, for he succumbed to a complication of pneumonia rather than to the malady for which he sought surgical aid.

The limits of space here available render it impracticable to give anything like an adequate account of the indefatigable and fruitful labors of Doctor Billings in the organization and in the development of the Institution, while allusion only may be made to his heroic services as a surgeon in the United States Army during the Civil War, to his extraordinary contributions to the collection and cataloguing of the world's medical literature, and to his equally extraordinary contributions to hospital and to library administration in America.* A just appreciation of his life and work must be left to biographers and to historians. We may write of him here only as a colleague in recent years and as a friendly associate in the promotion of American science during the past thirty years. He was a man of rare devotion to any duties or responsibilities he assumed, and without obtrusive evidence of the fact he manifested equal devotion in his more intimate friendships. For one preoccupied with the affairs of other organizations he gave a surprisingly large amount of time and attention to the affairs of the Institution. Of the sixteen

*Some account of his life and work may be found in memorial notices published in the Index Medicus for March, 1913; in a pamphlet giving an account of a memorial meeting held at The New York Public Library April 25, 1913; and in a memoir by Dr. S. Weir Mitchell, in Science, N. S., vol. XXXVIII, No. 989, Dec. 12, 1913.

meetings of the Board of Trustees held up to the present time he missed attending only one, when under surgical treatment in 1906; and of ninety-nine meetings of the Executive Committee, he attended all but thirteen. He was singularly alert, not only in his knowledge of the salient features of the Institution's work, but also in his acquaintance with most matters of detail. He brought to this work a breadth of learning and experience happily supplemented by an uncommon readiness in their effective application. Although he rarely manifested that sort of enthusiasm which springs from impulsive optimism, he had unlimited confidence in the ultimate efficacy of persistent efforts patiently and unostentatiously applied. He had no hesitancy in undertaking difficult enterprises and he shirked no labors they might entail. He was a man of few words, but these were in general peculiarly direct and cogent. He was at times severely destructive in his criticism of men and measures, but such criticism was usually justified, and although sometimes unfounded it has almost always been useful to the Institution. He was impatient with the verbosity and with the circuitous methods of obvious impostors, of whom the Institution has encountered not a few; but on the other hand, he was wont to show great consideration to sincere but deluded enthusiasts, with whom the Institution has also had to deal in no inconsiderable numbers.

The period during which Dr. Billings served the Institution has been one of swift growth, not unattended by difficulties and even dangers of a formidable character. It has been a period during which the Institution has evolved out of a chaos of conflicting opinions by aid of an unparalleled wealth of advice and suggestion and in the face of opportunities vastly greater than any single organization could possibly embrace. Among the essential qualifications of those charged with responsibilities under these conditions are a sense of humor and a sense of proportion. These Dr. Billings possessed in high degree. He was able to see readily that, while the Institution might develop in any one of innumerable ways, it would be impossible to develop in all of these ways simultaneously. His grim humor, supplemented by his wide knowledge of men, led him quickly also to appreciate the inevitable impracticability, if not futility, of a large majority of the projects suggested to the Institution for applications of its income; and the same qualifications prevented him from entertaining any illusions as to the capacity of that income. He saw plainly that most of the worthy enterprises commended to the Institution not only may be more advantageously left for other agencies to develop, but that, by reason of the necessarily limited scope and

income of any single organization, they must be so left. He stood firmly in opposition to all of the numerous plans suggested to the Institution for distribution of its income amongst educational, eleemosynary, governmental, and other organizations; and in opposition likewise to the still more numerous plans for dissipation of that income among a multitude of minor projects whose consummation could be better attained under other auspices. He thus rendered invaluable services during this formative period, when the Institution and its administration have been, properly enough in the interests of society, on trial, and when the only privilege it could claim was that of demonstrating a right to existence. But whatever may be the verdict of our successors with respect to this period, or however opinions of contemporaries may differ in respect to the actual development of the Institution, the independence, the fearlessness, the integrity, and the fidelity of Dr. Billings as a Trustee must stand forth as ideal characteristics of those altruistic and zealous individuals who lead the way to the enlightenment and to the advancement of our race.

The Institution has lost also during the past fiscal year another veteran colleague, who was long associated with Dr. Billings in the promotion of medical science, by the death on November 8, 1912, of Dr. Robert Fletcher, editor-in-chief of the Index Medicus since its publication was resumed by the Institution in 1903. A singular series of circumstances led up to the intimate association and warm friendship of these veterans. Each of them was educated for the profession of physician, each of them entered the United States Army as a volunteer surgeon at the beginning of the Civil War, each of them won honors "for faithful and meritorious services" at the front, and each of them later withdrew from active practice of his profession to enter upon more important life-work in the interests of medical science. Dr. Fletcher came into close cooperation with Dr. Billings in 1876, when the work of building up the Library of the Surgeon General's Office in Washington was begun. From a nucleus of a few hundred volumes at that time, this library has now come to contain more than a half million volumes of books and pamphlets. But in addition to this great work in which these men were so long associated, Billings had already projected the greater work of an index catalogue of existing medical literature and of a current catalogue for future additions to such literature. In these arduous enterprises Dr. Fletcher was chief coadjutor, and his continuous devotion to their editorial supervision during nearly four decades, extending almost to the day of his death in his ninetieth

year, affords an explanation at once of the high quality and the great quantity of the work accomplished.

Dr. Fletcher was a man of broad scholarship and of uncommon critical acumen. In manners and customs he belonged to what is often miscalled "the old school," but as a man of science he was distinctly modern and progressive, keenly appreciative of all real advances, and as keenly discriminating in dealing with unverified hypotheses. He was profoundly interested in the more recent researches of anthropology and he published a number of important papers in this most complex of all domains of inquiry. These and many scholarly papers on the history of medicine make a remarkable list of contributions to contemporary science. He took a conspicuous part in the development of the local scientific societies of Washington, whose work has proved to be of signal value in the departments of the United States Government. Thus he was in turn president of the Anthropological, the Philosophical, and the Literary societies of Washington, as well as president of that cosmopolitan social and intellectual association fittingly called the Cosmos Club. Personally, Dr. Fletcher was a most courteous and dignified gentleman, a model of industry, fidelity, and devotion in all his relations to his work and to his associates. His innate reserve and the habits acquired through the exigencies of military training and experience rendered him somewhat austere in appearance and in demeanor, and he did not conceal a Carlylean contempt for the ephemeral fancies and the popular shams of mankind, but his kindly counsel and his high sense of honor and duty made a lasting impression on all those who had the good fortune to share his confidence and friendship.

Other Events of the Year.

It is a source of satisfaction to record that the experience of the past year supplements that of a year ago in showing a general improvement in the relations which the Institution sustains to other organizations and to the world of learning at large. The obviously rational tendency to take an objective view of the Institution and its work and to measure them by the more permanent standards available is now everywhere distinctly visible. This tendency is manifested in many ways: by an increasing demand for exact information concerning the plan, scope, and development of the Institution as a whole; by an increasing critical interest in the investigations, the equipments, and the programs of work of our departments of research; and by an increasing demand for precise knowledge concerning special apparatus and special technique developed by our departmental staffs. In addition to these numerous

demands for correct information with respect to ways, means, methods, and results, there are now presented also, not infrequently, requests for investigations in cooperative enterprises for which other organizations, or in some cases individuals, are willing to supply the necessary funds. This is a manifestation which, while not unanticipated, has developed somewhat earlier than expected. It calls for considerate attention, since it is likely to grow with time in proportion as the Institution demonstrates capacity for trustworthy management of funds and for effective conduct of research.

On the death of Dr. Fletcher, November 8, 1912, editorial supervision of the Index Medicus was placed in charge of Dr. Fielding H. Garrison, who had long been associated as principal assistant with Dr. Fletcher in the publication of this work. Continuity of plan and purpose is thus assured in the perpetuation of this current bibliography, while the responsible editorship falls to one whose qualifications for the task have met the exacting standards of his eminent predecessors.

In accordance with the authorization voted by the Board of Trustees at its meeting of December 13, 1912, a department of human embryology, under the direction of Professor Franklin P. Mall, with a small staff of associates and collaborators, has been planned and is already engaged in active research. In arranging for this department the Institution is peculiarly fortunate not only in enlisting the directorship of Professor Mall, but in starting from a foundation furnished by his remarkable collection of human embryos. It will be seen also that this enterprise is of far greater import than might at first appear, for it has fundamental relations to the science of anthropology as well as to those of anatomy, physiology, and pathology, which latter, indeed, from some points of view, may not improperly be regarded as branches of the former widely inclusive science. The efforts of the Institution to enter the domain of anthropology, to which reference is again made in a later section of this report, are thus in part realized in a most effective way.

Another noteworthy event of the year is the construction of two new buildings, a heating and lighting plant, and an additional laboratory, for the Department of Experimental Evolution, authorized by the Board of Trustees at their last meeting. Plans in illustration of these buildings, which are now nearing completion, will be found in connection with the annual report of the department in the current Year Book. Two of the many uses which this laboratory is designed to serve in the immediate future are those of housing and further experimentation upon the unique collection of pedigreed pigeons, studied for many years by the late Professor C. O. Whitman, whose

researches the Institution has undertaken to complete and to publish. In accordance with the agreement entered into with Professor Whitman's heirs this unrivaled collection of biological material will become the property of the Institution, and arrangements have been made for its transfer to Cold Spring Harbor from Chicago before the end of the calendar year.

Similarly, two items from the current history of the Department of Terrestrial Magnetism are worthy of mention here. One of these is the approaching completion of an office and laboratory building whose construction was approved by the Board of Trustees a year ago. Floor plans of this building are incorporated in the annual report of the Director of the department in the current Year Book. The building is situated on a very favorable, elevated site of a little less than seven acres in the District of Columbia, near Chevy Chase, and near the western boundary of Rock Creek Park. It will be fireproof, will furnish safe storage for the extensive records already acquired by the department, and will afford opportunity for experimental researches in terrestrial magnetism which may be confidently expected to give deeper insight into this obscure but at present highly utilitarian property of our planet. The other noteworthy event referred to is the near completion of a circumnavigation voyage of about three and a half years' duration and of courses aggregating 92,000 miles, in round numbers, by the non-magnetic ship *Carnegie*. Experience with this ship shows that a magnetic survey of the oceans is a somewhat less formidable undertaking than a magnetic survey of the continents, for the latter are still, on the whole, less accessible than the former since the advent of this non-magnetic nautical observatory. Great credit is due to Mr. W. J. Peters, commander of this ship, for assiduous attention not only to her safety, but also to the effectiveness of her mission in the immediate interests of the world's navigation and in the more important, though less obvious, interests of terrestrial physics.

Reference was made in the report of a year ago to the construction of a fireproof office building at Pasadena, California, for the staff of the Solar Observatory. This building has been occupied during the past year, and its characteristics are shown by illustrations in photo-perspective and in plan in the current Year Book. In addition to supplying appropriate quarters for the departmental staff and storage for the accumulating records of the Observatory, it furnishes in its sub-basement a constant-temperature room in which will be installed a dividing engine designed especially to rule diffraction gratings for use with the other optical apparatus of the Observatory.

Such an engine has been constructed at the shops of the Observatory during the past year by Mr. Jacomini, mechanician of the departmental staff, in collaboration with Dr. John A. Anderson, of Johns Hopkins University, who has supplied tests of precision which have led to a highly satisfactory degree of perfection in this excessively difficult and delicate kind of construction. It is gratifying to report also in this connection that the glass disk for the 100-inch telescope, which a year ago had developed distortions indicating defective stability, is now meeting all essential requirements and giving promise of an optical surface equal to, if not superior to, that of the 60-inch mirror. Accordingly, work of construction for the foundation and for the mounting of this 100-inch telescope is now proceeding as rapidly as the conditions of safety and of efficiency in such a novel undertaking will permit.

OUTLINE OF RESEARCHES OF THE YEAR.

Limitations of Administrative Reports.

As is abundantly indicated in previous reports, and as is evident to any deliberate reader of the bewildering miscellanies presented in the Year Books, the diversity and the complexity of the investigations going forward under the auspices of the Institution preclude anything like a clear and complete summary of their scope, progress, and prospective value within the limits of an administrative report. The general reader must take it for granted (provisionally at least) that these investigations are in the main worth undertaking and thus await the verdict of time through the aid of a growing critical public opinion; for in proportion as such investigations are fundamental, and hence worth carrying on, they will be difficult of exposition and more difficult of comprehension. Concerning this matter there appears to be prevalent a popular fallacy to the effect that writers untrammeled by competent scholarship, but who possess verbal facility, are better qualified to expound a technical subject than those who have developed it or contributed thereto; and along with this fallacy there is frequently coupled another to the effect that ours is an age of narrowing specialization, whose evil effects may be remedied by resort to literary views of phenomena and by restricting the range of increasing knowledge. While patiently tolerant with these extremes of opinion, it is obviously inadmissible to adopt either of them here. We may neither pretend to exposition of knowledge not acquired nor deprecate the excess of knowledge possessed by experts in this or that field of science. It is hoped, therefore, that the brief summaries

given in the President's reports may not be mistaken for adequate accounts of current progress or for sufficient recognition of the merits of the researches referred to.

Departments of Research.

In accordance with the views just set forth it seems appropriate at this time to limit still more narrowly than hitherto the brief summaries of departmental work and to invite attention still more directly to the departmental reports published in the Year Book. All of the departments of research of the Institution hitherto reported upon are now well-defined organizations, each of them independent of and more or less isolated from the others, and each of them devoted to a field which, while in some cases related to, does not encroach upon, the fields of others. Each of them possesses thus a degree of autonomy which calls for a corresponding degree of freedom in the rendition of annual reports and accounts of progress. But along with this autonomy, indispensable to the highest efficiency in such organizations, it is equally essential that there should coexist a fraternity of interest and a solidarity of purpose centering in the Institution as a whole. First steps toward development of these latter desiderata were taken in December, 1909, on the occasion of the annual meeting of the Board of Trustees, when the Administration Building was dedicated and when the directors of departments of research were invited to give exhibits of the salient features of their work up to that time. On the same occasion two related experiments were inaugurated, namely, that of a lecture to the Trustees and their guests from the head of a department of research, and that of a conference between the directors of departments and the President. The results of these experiments have been so favorable that the plan of having an annual lecture, an annual conference, and exhibits of departmental work at intervals of three to five years, has come to be adopted by common consent. In addition to the exhibit held in December, 1909, another was held in December, 1911, on the occasion of the tenth anniversary of the foundation of the Institution.

By reason of the decision of the Board of Trustees a year ago to take part in the Panama-Pacific Exposition, to begin in San Francisco in February, 1915, it is proposed to hold the next departmental exhibit in the Administration Building at the time of the meeting of the Board of Trustees in December, 1914. It will thus be practicable to bring together an aggregate from which (by aid of counsel from departmental representatives) a more restricted exhibit may be drawn for the Panama-Pacific Exposition. On account of this cir-

cumstance and on account of the fact that the departments on the average, as well as the present administration, will have completed a first decade in the Institution's history a year hence, it seems desirable to reserve any more elaborate summaries of work accomplished and now under way, whether of departments or of research associates, until that time. Accordingly this section of the present report is limited to something less than the usual extent.

Department of Botanical Research.

Studies of the Salton Sea,* carried on during the past seven years by this department in collaboration with a number of contributing specialists, have been brought together during the year in a volume now in press under the title "The Salton Sea: A study of the geography, the geology, the floristics, and the ecology of a desert basin," as publication No. 193. A great number of interesting questions in geography, geology, botany, chemistry, micro-biology, plant physiology, climatology, etc., are discussed in this volume. Of these, an instructive abstract is given by the Director in his current report.

Among many researches carried on by the Director, mention may be made of his cultivation of second and third generations of mutants arising from ovarial treatments of plants and resulting in further noteworthy morphological and physiological departures from the original parent stocks. Of members of the departmental staff, Dr. Cannon has extended his fruitful studies of root systems of desert plants to include the corresponding characteristics of trees in the coastal climate of California and to the problem of treelessness in prairie regions. Dr. Forrest Shreve has given special attention to the factors involved in the transpiration of rain-forest plants and to the effects of mountain slopes and climatic conditions varying with altitudes and with exposures. Dr. Spoehr has continued his investigations of the action of light and heat in producing chemical changes in plant organisms, giving promise thus of important advances in the newer field of phytochemistry and photolysis.

Several collaborators have contributed to the varied work of the department during the year. Sections of the Director's report are thus devoted to accounts of the further experiments of Professor W. L. Tower on the evolution of chrysomelid beetles, for which facilities are provided at the Desert Laboratory; to the physical studies of

*Often by earlier writers called Cahuilla Basin, more frequently called Salton Sink, and now called Blake Sea, in honor of Professor Blake, who, as geologist of the Williamson survey of 1853, first accurately interpreted this remarkable depression below sea-level.

Professor B. E. Livingston, formerly a member of the departmental staff, on the water relations of plants; to the determinations of autonomic movements in opuntias by Mrs. Shreve, whose volume on "The daily march of transpiration in a desert perennial" is in press as publication No. 194; to the investigation of Professor H. M. Richards on the acidity, the gaseous interchange, and the respiration of cacti; to the surprising properties of the opuntias in fruit development, brought to light by Professor D. S. Johnson; and to the favorably progressing enterprise undertaken by the department, in collaboration with Dr. N. L. Britton and Dr. J. N. Rose, for a systematic determination of the distribution and relationships of the cactus family of plants.

Department of Experimental Evolution.

The work of the year in this department records, among many other advances, additional contributions to the laws of human inheritance; the results of further and more conclusive studies of the transmission of traits in plants of the genera *Bursa* and *Oenothera;* and some preliminary indications of specially instructive investigations in the field of biochemistry. The Director has divided his time between researches based on breeding experiments carried on at his station and studies of data bearing on human heredity collected under the auspices of the Eugenics Record Office, of which he is also the directing head. In addition to the researches carried on by Doctors Banta, Gortner, Harris, and Shull of the resident staff, Dr. A. F. Blakeslee, Dr. G. C. Bassett, and Professor John H. Gerould have pursued investigations in collaboration with this staff. One of the most important of these cooperative enterprises is the joint investigation of Dr. Blakeslee and Dr. Gortner on the low organisms called mucors, from which it appears that sex-differentiation in these organisms has a determinate physical basis. This conclusion appears to bear a close relation to similar fundamental conclusions reached independently in other lines of work by our Research Associates, Dr. Reichert and Dr. Osborne.

The exigencies of his experimental work going forward at the departmental station have prevented Dr. Shull from completing the manuscript of his account of the work of Luther Burbank. It has been arranged, therefore, that he shall spend some months abroad, beginning with October, 1913, in order that uninterrupted attention to this manuscript may enable him to finish it without undue delay. The importance of the biochemical laboratory, in charge of Dr. Gortner in connection with the department, has been well attested during the year by the aid he has rendered in the complex studies

evidently essential to further advances in the problems of plant and animal evolution. The more adequate provision for this laboratory adjunct furnished by the new departmental buildings, already referred to, will make it practicable to utilize still more advantageously the highly developed qualitative and quantitative methods and data of the older science of chemistry.

Department of Economics and Sociology.

Substantial progress toward completion of the several contributions from the twelve divisions of this department to their projected basis for a social and economic history of the United States is reported by Professor Henry W. Farnam, Chairman of the department. It is estimated by him that six of the divisions will be able to present final reports within the next fiscal year. These are the divisions of Population and Immigration, in charge of Professor Willcox; Mining, in charge of Mr. Parker; Transportation, in charge of Professor Meyer; Domestic and Foreign Commerce, in charge of Professor Johnson; Labor Movement, in charge of Professor Commons; and Social Legislation, in charge of the Chairman. Delays due to the requirements of their primary occupations, to ill health or misfortune in the case of some collaborators, and to demands of public service in other cases, have prevented the remaining divisions from bringing their work to a similarly forward state.

The Chairman again calls attention in his report to the desirability of reorganizing this department and placing it on a basis similar to that of all other departments of research of the Institution. As to the appropriateness of this recommendation, there now appears to be no dissent, either within or outside the department. It is hoped, therefore, that such a reorganization may be consummated as soon as the work now in hand may be completed in accord with the original plan, if it should not appear advantageous to make the obviously desirable change at an earlier date. There is no doubt that the field of opportunity for effective pioneer work by such a department is in great need of present-day cultivation and that it extends indefinitely into the future.

The Geophysical Laboratory.

The preliminary stages in the development of this hitherto unique establishment may now be said to have passed, since laboratories similarly equipped and for like purposes are now being set up under other auspices. That the merits of the methods, the apparatus, and the earlier published researches of the Geophysical Laboratory should have been thus early recognized is at once a source of gratification to the Institution and an

additional stimulus to fundamental work in the difficult but ever fruitful domain of geophysics. In his annual report the Director gives instructive accounts of the effects of pressure in the formation of minerals, of progress in the perfection of adequate appliances for calorimetric measures of minerals, of the factor of temperature in optical studies of crystals, of the results thus far obtained in volcano studies, and of the important economic investigations (now under way at the Laboratory) of the secondary enrichment of copper sulphide ores. It had been hoped that the signal success attending the studies of Kilauea a year ago might be followed up during the past year, but in this the staff has met disappointment, for the volcano has been inactive and gives no warning of renewed opportunities.

The activities and productivities of the Laboratory staff are indicated impressively by the 47 papers issued during the year, or now in press, reviewed in the report of the Director. These have been, or will be, published in current journals. Several of them appear as duplicates by reason of translations into the French or the German languages; of these, it is interesting to note that a translation into French by Professor P. Chappuis has been made (for the Journal de Physique) of the work of Day and Sosman on "High temperature gas thermometry," publication No. 157 of the Institution.

Department of Historical Research.

The purposes to which this department is devoted and the programs it proposes to follow have been outlined in the Director's annual reports of the past seven years. He took occasion also, in December a year ago, when he gave the annual Trustees' Lecture, entitled "The future uses of history," to present a fuller statement of these purposes and programs, as well as to indicate the role which history may fittingly play in the evolution of the social organizations which must occupy the attention of our successors. This instructive lecture was rendered available to a wider circle of interested students of history by publication in The History Teachers' Magazine for February, 1913.

Briefly stated, the main purposes of the department are two: first, to furnish aids, guides, and reports which may give appropriate direction to the writers of monographs and general histories; and, secondly, to furnish full textual publication of important historical documents. Under the first of these heads the Director reports very favorable progress toward completion of a series of three guides to the materials for American history in London archives and in the libraries of Oxford and Cambridge Universities. The first volume of this series was issued as No. 90 of the Institution's publications in

1908, and the other two volumes, now nearly through the press, are designated 90A and 90B respectively. As to this series the Director remarks in effect in his report that no similar inventory of like extent, concerning archive materials which London possesses for the history of any other nation, has ever been issued. Two additional volumes in this first division of activities have appeared during the year, namely, publication No. 163, Guide to materials for United States history in Mexican archives, by Herbert E. Bolton; and publication No. 172, Guide to materials for United States history in Canadian archives, by David W. Parker. Under this head also progress is reported in the work of Mr. Leland on materials for American history in Paris archives, in the work of Professor Hill in Spanish archives, and in the corresponding work of Professor Faust in Switzerland and in Austria. Under the head of textual documents the Director refers in some detail to progress in the preparation of the projected collections of "Letters of delegates to the Continental Congress," of "European treaties bearing on United States history," of "Proceedings and debates of Parliament respecting North America, 1585 to 1783," and to a preliminary report on papers of the Royal African Company in the Public Records Office of London.

Attention is especially invited to the Director's interesting review of the work of the department during the first decade of its existence, completed with this fiscal year. Some idea of the extent of this work may be gained from the list of departmental publications cited, the number of these being 17, with an aggregate of over 5,000 pages; while the bulky correspondence of the Institution as a whole is in some degree indicated by the fact that this department records an aggregate of upwards of 20,000 letters in its decennial inventory.

Department of Marine Biology.

When the laboratory of this department was established on Loggerhead Key, Dry Tortugas, Florida, now nearly ten years ago, Fort Jefferson, on an adjacent island, was an important base station of the United States Navy and transportation to and from points on the Gulf coast was a matter of daily occurrence. In the meantime, however, this station has steadily diminished in importance and is now virtually abandoned as a naval base. This change of conditions shifts the burden of transportation between the laboratory and the nearest port, Key West, about thirty miles distant, wholly upon the department; and the resulting increased cost and inconvenience have led the Director to recommend a gradual transfer of his laboratory and activities to a more favorable site. Preliminary investigations indicate that such a site

may be had in Jamaica, where health conditions and transportation facilities have been much improved in recent years, where the cost of labor and subsistence is low, and where such an international scope as best befits marine biology could be readily developed. It may be anticipated that definite plans for an advantageous change of site will be matured during the coming year and ready for submission to the Board of Trustees in December, 1914.

The department has suffered serious loss during the year in the untimely death of a remarkably able Research Associate, George Harold Drew. It has met with a reverse also in the temporary illness of another Research Associate, Dr. T. Wayland Vaughan. Drew and Vaughan had under way important investigations, originating at Tortugas, for the furtherance of which the departmental expedition of this year to Torres Straits was largely planned and authorized. Drew had made the discovery at Tortugas that the so-called coral mud in that vicinity is not due to corals, but has been precipitated through the chemical agency of a bacillus abundant in the surface waters of the tropical Atlantic. Vaughan, on the other hand, had made quantitative studies of the growths of coral organisms at Tortugas and of the closely correlated deposits or reefs. Jointly their investigations promised a solution of the long-vexed problem of the origin of such reefs and it was hoped that the expedition to Torres Straits and Great Barrier Reef would enable them to secure the additional data essential to final proof. In spite of these adversities, however, the Director and four associates sailed from San Francisco for Sidney, Australia, on July 23, 1913, and arrived at Torres Straits early in September. When last heard from, in September, the party was reported all well on Murray Island.

The laboratory season at Tortugas extended from April to June, inclusive, and twelve collaborators availed themselves of the facilities afforded for their researches. Summaries of these are given by the Director in his current report, while more elaborate accounts are furnished by the investigators themselves in appendices to that report. Two additional volumes of contributions from the Tortugas Laboratory are in press as publications Nos. 182 and 183.

Department of Meridian Astrometry.

On the death, October 5, 1912, of Professor Lewis Boss, Director of this department since its establishment in 1906, his son, Mr. Benjamin Boss, long associated with his father in meridian astrometry, was made Acting Director. Adherence to the original program, so indispensable to the formidable enterprise this department has under way, is thus assured.

The extensive computations essential in the derivation of the great number of stellar positions observed at the temporary observatory at San Luis, Argentina, are going forward at a favorable rate, so that the inclusive catalogue of precise positions for stars in both hemispheres may be expected in due time. Some instructive results of these computations, showing the stability of the San Luis meridian mark (mire), the diurnal variation of the clock corrections, and the changes of personal equation for day and night observations are given in the report of the Acting Director.

As in most lines of fruitful research, the work of this department is noteworthy for its by-products, or for contributions it is making to allied lines of inquiry. Obviously, a first requisite to a knowledge of stellar motions lies in precise determinations of stellar positions at different epochs. The so-called proper motions of stars are thus brought to light, and from these it is possible to determine also the motion of our solar system. But now comes the surprising discovery that these proper motions, hitherto supposed to be of a random character, are of a systematic nature dependent in large degree, apparently, on the stage in evolution any individual star has reached and on the group to which it belongs. A new and peculiarly fascinating field is thus opened to astronomers of all kinds, and the by-products referred to seem destined to prove not less important than its primary object in positional astronomy. The world of astronomy, however, is anxiously awaiting the attainment of this object, as is well shown by the fact that the preliminary catalogue issued by the department three years ago is already out of print.

The Nutrition Laboratory.

One of the reasons which helped seven years ago to determine the location of this laboratory was found in the expectation that several hospitals would be erected in the near vicinity. This expectation has now been realized by the completion during the past year of the Peter Bent Brigham Hospital, the Collis P. Huntington Memorial Hospital, and of two hospitals for infants and children respectively. The environment and the opportunities for securing pathological subjects as well as clinical cooperation and counsel are therefore highly favorable for the researches undertaken by this establishment. That it has entered a fruitful field of activity is well attested by the wide interest shown in its publications already issued, by the desires of experts at home and abroad to learn of the ways and means employed, and by the duplication in laboratories of other countries, as well as in those of America, of the apparatus developed.

But science is cosmopolitan, and although many novel enterprises may be said to have originated with the Institution, it may not lay claim to any monopoly in research; it can only contribute here and there in a limited degree to the ever expanding aggregate of verifiable knowledge. In recognition of these limitations the Director has appropriately adopted the plan of inspecting, at frequent intervals, the laboratories, the special apparatus, and the technique developed elsewhere for the same and allied work. Thus he has made during the past year a third triennial tour of European laboratories, hospitals, etc., devoted to such work. This has afforded opportunity for numerous advantageous conferences with colleagues and for the selection of new apparatus of proved utility; while the Director has been able during the same time to give counsel in respect to the adoption in other laboratories of apparatus and methods similar to those of the Nutrition Laboratory. The latter, therefore, like the Geophysical Laboratory, is no longer distinguished by its singularity, but must now enter upon a career of friendly rivalry with many cognate establishments.

For details of the investigations of the year, reference must be made to the Director's report. They are summarized by him under thirteen principal heads, which range from studies of metabolism in infants, through those of normal metabolism in adults, up to studies of chronic starvation and diabetes mellitus. Many publications issued or in press during the year are also reviewed by the Director in his report. Considerable new apparatus has been acquired and earlier forms of equipment have undergone modifications suggested by experience. Interesting mention is made of visiting and cooperating investigators, of the special researches of the laboratory staff, and of the conferences had by the Director during his trip abroad. The staff has been enlarged during the year by the addition of Professor Raymond Dodge, who will undertake work in the psychology of nutrition, and by Mr. E. H. Lange, who will serve as physicist for the staff.

Department of Terrestrial Magnetism.

As already indicated in an earlier section of this report, one of the noteworthy events of the year for this department will be the completion of the second cruise of the non-magnetic ship *Carnegie*. She is now on the last stretch of this cruise and may be expected to arrive at a home port before the end of the calendar year, having been continually in service since June 20, 1910. The aggregate distance traversed in her two cruises will be in round numbers 100,000 miles. The corresponding

distance covered by the chartered ship *Galilee*, in the Pacific Ocean during 1905–1908 is 60,000 miles. Thus the total distance traversed up to date in the magnetic survey of the oceans is 160,000 miles, or about six times the circumference of the earth. Accurate magnetic data have been obtained thereby in all of the oceans between the parallels of 50° north and 50° south latitude, or near the courses usually followed by vessels. By reason of the expedition attained in deriving from these surveys the results of chief interest to mariners, it has been practicable for chart-publishing establishments to make prompt revision of defective sailing charts or to issue corrections thereto; and a distinct improvement in these aids to navigation is already noticeable in the charts issued by the leading maritime nations. The more complete results of these ocean surveys are also in a forward state of preparation and it is expected that a full account of the work accomplished by the *Galilee* and the *Carnegie* will be ready for publication a year hence. In the near future it is considered that the *Carnegie* should make surveys in areas not yet covered and along some stretches already traversed where cloudy or stormy conditions have prevented the securing of adequate observations. She will at the same time cross her previous tracks as often as practicable in order to determine for such intersections the information now most needed by chart-makers, namely, the annual changes in the magnetic elements.

Magnetic surveys of land areas are also proceeding at a favorable rate. An expedition under Mr. D. W. Berky, assisted by Mr. H. E. Sawyer, has traversed the Sahara Desert, starting from Algiers near the end of October, 1912, and arriving at Timbuktoo May 12, 1913; and these observers are now extending their work into the territory of west and central Africa bordering on the Atlantic. Dr. H. M. W. Edmonds has led an expedition into Canada, west of Hudson Bay, into the region of one of the foci of maximum intensity of the earth's magnetic field. Mr. A. D. Power has made noteworthy progress in a survey of northeastern South America, including a trip along the Orinoco River and the Rio Negro from the mouth of the Orinoco to Manaos on the Amazon. Mr. H. F. Johnston is engaged in a series of determinations along a line running northward from Montevideo towards Manaos. Similarly, the magnetic survey of Australia and the adjacent islands is making efficient progress under the immediate charge of Mr. E. Kidson. Under his guidance Mr. E. N. Webb was trained for and supplied with instruments for the valuable magnetic work accomplished by the Mawson Antarctic expedition.

In the near future it is anticipated that the department will have sufficient data to permit the construction of a new set of magnetic charts, including all three magnetic elements (declination, dip, and intensity), especially for that part of the globe included between the parallels of 50° north and 50° south of the equator. It will then be practicable to study the general problem of the earth's magnetism by aid of a large mass of homogeneous data surpassing in definiteness any mass hitherto available for this purpose. In anticipation of the need of experimental facilities for studies of this problem and others closely related thereto the office and laboratory building of the department was authorized a year ago and is now approaching completion, as explained in a previous section of this report. For the conduct of experimental researches the department has secured the services of Dr. W. F. G. Swann, late of the University of Sheffield. Mr. Charles R. Duvall, late of the U. S. Coast and Geodetic Survey, has also recently joined the office staff to fill the position of expert computer.

Attention is invited to the Director's remarks on the present status of the department's work, to the account of his own researches of the year, and to his programs for further work. And in the interests of further possible work of construction of buildings under the auspices of the Institution, it may be worthy of note that preliminary plans for the new laboratory were well matured by Mr. Fleming, engineer of the departmental staff, before consulting an architect, and that supervision of construction has also been assigned to Mr. Fleming. This method of procedure, which has been followed in several instances by the Institution, appears to be highly advantageous for economy and for efficiency.

The Solar Observatory.

From the date of its establishment nine years ago this observatory has been one of the most important of the enterprises fostered by the Institution. It has called for heavy annual appropriations; it has grown with extraordinary rapidity and with equally extraordinary productivity; and it is now an organization whose staff of investigators, research associates and collaborators, constructors, computers, designers, mechanicians, and operators includes upwards of sixty individuals. By reason of the widespread popular and technical attention given to astronomical science, and by reason of the novel equipment of this observatory and the relatively new field entered by it, the world looks with special interest on its development, quite apart from the keen general interest in the contributions it has made and may be expected to

make to astrophysics. This special interest centers in the fact that the experience of the observatory furnishes the details of an experiment on a large scale in a difficult field of inquiry, for which ways and means of corresponding magnitudes have been available. In general the means at hand for such enterprises have been incommensurate with the obstacles to be overcome, and progress has been hindered, delayed, or blocked until necessity has devised some indirect way of surmounting these obstacles. But, on the other hand, this necessity has hitherto exerted a highly beneficial influence in stimulating discovery and invention, and one may perhaps question whether in the past ampler means for the pursuit of systematic research would have been on the whole advantageous for the advancement of knowledge. Some eminent authorities, indeed, still question the propriety of the endowment of research in any but educational establishments. Contemplative minds are therefore awaiting the results of the experiment of the Solar Observatory with an eagerness only exceeded by that of the popular mind for information concerning the latest discoveries and advances in astronomical science.

In the meantime, with the installation of additional equipment and the application of appropriate methods of research, the observatory is increasingly productive. The principal results of the work of the past year are summarized by the Director in his current report under seventy-two heads. No further summary of these results may be attempted here; attention may be given to a few only of the salient items of interest suggested by the report as a whole. The year has been one of minimum solar activity and noteworthy for a nearly complete absence of sun-spots. This has proved advantageous for the pursuit of studies of the sun's magnetism now definitely proved by work done at the observatory during the year. This advance in solar physics is of the highest interest by reason of its probable relations to terrestrial magnetism and to cosmic physics. Stellar and laboratory work have gone forward at a highly productive rate, and the subjects of solar, stellar, and laboratory spectra and stellar velocities are among those instructively considered in the Director's report. Evidence has been accumulated tending to show that light is absorbed in space, and that such a phenomenon will not only elucidate others hitherto obscure, but furnish means of measuring the greater depths of the visible universe. Professor Kapteyn has continued to act as Research Associate and adviser in the program of researches undertaken. The important results attained by Professor Störmer, who spent some time at the observatory as a Research Associate in 1912, in his investigation of solar

vortices, and those of other collaborators and members of the observatory staff, present features of special interest in the departmental report.

Favorable progress has been made in grinding the glass disk for the 100-inch telescope since the source of the obstacle encountered in this work was discovered about a year ago. The disk has been subjected to severely critical tests, which give assurances that it will meet requirements. The preparation of a 60-inch plane mirror for testing the 100-inch reflector has gone on simultaneously with work on the latter. The heavier parts of the mountings for the telescope are now under construction by the Fore River ship yards at Quincy, Massachusetts, while the foundations on Mount Wilson and the dome superstructure will probably be completed as soon as the disk and its mountings are ready. Allusion has already been made in a previous section to the new office building at Pasadena and to the remarkable success achieved in the construction of a dividing engine for ruling diffraction gratings; for adequate accounts of these and numerous other subjects of interest reference must be made to the Director's full report.

Work of Research Associates and Collaborators.

As indicated in previous reports, the complexity of the relations which Research Associates and collaborators sustain to the Institution is so great as to preclude any comprehensive explanation within the limits allotted to an annual administrative report. Their work embraces a wide range of subjects and varies in its conduct from individual independence to intimate collaboration with the departments of research and with the division of publications. During the past year more than twenty distinct fields of research have been cultivated and a total of more than one hundred investigators have contributed to the output. Summaries of the work of associates proceeding independently are given by them in the current Year Book. Their publications of the year are cited in the bibliographical lists of later sections, and the work of many collaborators is mentioned in departmental reports. Attention may be called, among many important researches, to that of Professor H. N. Morse on the osmotic pressure of solutions, now approaching completion; to the investigations of Professor Mall and colleagues in embryology; to the completion of the edition of the Arthurian Romances by Dr. H. Oskar Sommer, by the publication during the year of the seventh volume of this monumental contribution to the medieval sources of modern literature; to the appearance during the year of a translation into German of the

work on "Dynamic meteorology and hydrography," the Institution's publication No. 88, by Professor V. Bjerknes; to the significant studies of Professors Osborne and Mendel in extension of their researches on the vegetable proteids; to the fundamental investigations of Professor Reichert, brought out in publications Nos. 116 and 173; and to the penetrating contributions to philology embodied in the series of researches of Mr. William Churchill, published in Nos. 134, 154, 174, and 184.

FINANCIAL RECORDS.

Financial Statement for Fiscal Year 1912-1913.

The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unallotted and unexpended at the end of the year are shown in detail in the following statement:

Object of appropriation.	Balances unallotted Oct. 31, 1912.	Appropriation Dec. 13, 1912.	Revertments Nov. 1, 1912, to Oct. 31, 1913.	Total.	Aggregates of allotments and amounts expended and transferred.	Balances unallotted Oct. 31, 1913.
Large grants...	....	$816,972	$21,287.75	$838,259.75	$838,259.75	....
Minor grants...	$6,213.49	116,800	8,229.48	131,242.97	125,980.41	$5,262.56
Publications....	16,881.18	60,000	5,315.33	82,196.51	66,693.30	15,503.21
Administration.	....	50,000	5,000.00	55,000.00	55,000.00	....
Reserve fund...	....	250,000	....	250,000.00	250,000.00	....
Insurance fund..	....	25,000	....	25,000.00	25,000.00	....
Total....	23,094.67	1,318,772	39,832.56	1,381,699.23	1,360,933.46	20,765.77

The following list shows the departments of investigation to which the larger grants were made by the Trustees at their last annual meeting and the amounts allotted from these grants by the Executive Committee during the year:

Department of Botanical Research..................	$38,005.00
Department of Experimental Evolution...............	95,141.75
Geophysical Laboratory..........................	78,000.00
Department of Historical Research..................	29,600.00
Department of Marine Biology......................	31,890.00
Department of Meridian Astrometry................	25,180.00
Nutrition Laboratory..............................	46,549.00
Division of Publications (office expenses).............	9,000.00
Solar Observatory................................	165,631.00
Department of Terrestrial Magnetism................	210,263.00
Researches in Anthropology........................	7,000.00
Researches in Embryology..........................	15,000.00
	751,259.75

The fields of investigation to which minor grants were assigned, the names of the grantees, and the amounts of the grants are shown in the following list:

Details of minor grants.

Field of investigation.	Names of grantees.	Amounts of grants.
Astronomy	Kapteyn, J. C	$2,000.00
Archeology	Bandelier, Adolf F	2,000.00
	Van Deman, E. B	1,800.00
Bibliography	Index Medicus	12,500.00
Biology	Riddle, Oscar	5,600.00
	Watson, John B	500.00
Botany	Britton, N. L., and J. N. Rose	6,900.00
Chemistry	Acree, S. F	2,000.00
	Baxter, G. P	1,500.00
	Osborne, T. B., and L. B. Mendel	15,000.00
	Jones, H. C	3,200.00
	Morse, H. N	4,000.00
	Noyes, A. A	3,000.00
	Richards, T. W	3,000.00
	Sherman, H. C	1,200.00
Geology	Chamberlin, T. C	4,000.00
	Moulton, F. R	2,000.00
History	Osgood, H. L	1,200.00
Literature	Bergen, Henry	1,800.00
Marine Biology	Drew, G. Harold	2,000.00
	Vaughan, T. Wayland	3,300.00
Mathematics	Morley, Frank	1,200.00
Metallurgy	Howe, Henry M	500.00
Meteorology	Bjerknes, V	1,800.00
Nutrition	Tigerstedt, Carl	1,000.00
Paleontology	Case, E. C	2,000.00
	Hay, O. P	3,000.00
	Wieland, G. R	3,000.00
Paleography	Loew, Elias A	1,800.00
Physics	Hayford, J. F	2,000.00
	Nichols, E. L	3,000.00
	Barus, Carl	500.00
Physiology	Cooke, Elizabeth	1,900.00
	Reichert, E. T	1,500.00
Zoology	Castle, W. E	1,000.00
	Naples Zoological Station	1,000.00
Administration Building (additions)		5,792.66
Reception, National Academy of Sciences		1,000.00
International Phytogeographical Association		1,200.00
		111,692.66

The following grants for publication were authorized during the year:

Andrews, C. M.	$2,006.22
Barus, Carl	900.00
Benedict, F. G., and E. P. Cathcart	2,200.00
Bergen, Henry	170.00
Cannon, W. A.	2,000.00
Case, E. C., S. W. Williston, and M. G. Mehl	1,200.00
Castle, W. E., and C. C. Little	2,100.00
Castle, W. E., and J. C. Phillips	650.00
Davenport, C. B	800.00
Churchill, William, and J. P. Finley	2,000.00
Huntington, E	3,800.00
Index of U. S. Documents relating to Foreign Affairs	12,000.00
Jones, H. C.	1,400.00
Jones, H. C	1,500.00
MacDowell, E. C., and W. E. Castle	600.00
MacDougal, D. T., et al	4,200.00
Osgood, C. G	9,000.00
Papers from the Tortugas Laboratory	3,800.00
Reichert, E. T.	1,094.68
Shreve, Edith B	700.00
Smith, E. F.	4,800.00
Sommer, H. O	6,500.00
Walcott, C. D.	272.40
Weed, L. H	1,600.00
Wright, Albert Hazen	1,400.00
	66,693.30

The sources and amounts of the revertments from November 1, 1912, to October 31, 1913, inclusive, are shown in the following list:

Large grants:		
Transferred from minor grants	$3,287.75	
Revertment, Division of Publications	3,000.00	
Revertment, Department of Meridian Astrometry	15,000.00	
		$21,287.75
Minor grants:		
Cooke, Elizabeth, Grant No. 878	550.00	
Drew, G. Harold, Grant No. 854	2,000.00	
Fitting, Hans, Grant No. 816	1,800.00	
Historical Research, Department of, Grant No. 794	90.00	
Osborne, T. B., Grant No. 692	83.32	
Reception, National Academy of Sciences, Grant No. 879.	381.16	
Terrestrial Magnetism, Department of, Grant No. 798	25.00	
Vaughan, T. Wayland, Grant No. 855	3,300.00	
		8,229.48
Publication:		
Barus, Carl, Grant No. 872	353.50	
Benedict and Joslin, Grant No. 820	284.00	
Bergen, Henry, Grant No. 826	7.13	
Burnham, S. W., Grant No. 803	884.15	
Callaway, Morgan, Jr., Grant No. 802	11.00	
Cannon, W. A., Grant No. 824	531.70	
Carnegie Institution of Washington, Grant No. 667	218.73	
Churchill, William, Grant No. 801	851.08	
Farlow, W. G., Grant No. 63	365.00	
Jones, Harry C., Grant No. 819	33.05	
Lancaster, H. C., Grant No. 814	309.70	
Loeb, Leo, Grant No. 821	323.06	
Researches of the Department of Terrestrial Magnetism, Grant No. 818	1,143.23	
		5,315.33
Administration:		
Revertment from allotted balance		5,000.00
		39,832.56

Summary of Receipts and Expenditures of the Institution to date.

The aggregates of receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by the following table; the grand total of these to date is $8,680,575.54.

Year ending Oct. 31—	Interest. Endowment.	Interest. Bonds and bank deposits.	Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
1902	$250,000.00	$9.70	....	....	$1,825.52	$251,835.22
1903	500,000.00	5,867.10	$2,286.16	....	101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	$999.03	....	536,439.36
1905	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.77
1911	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.92
1912	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.43
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
Total..	7,678,355.00	249,661.81	82,263.84	19,123.51	*651,171.38	8,680,575.54

*Of this amount $640,500 were received from the sale of bonds in 1908, 1909, 1910, 1912, 1913.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads: (1) investments in bonds and on account of Administration Building; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The following table shows the actual expenditures under these heads for each year since the foundation of the Institution:

Year ending Oct. 31—	Investments in bonds and on account of Administration. Building.	Large projects.	Minor projects, special projects, research associates and assistants.	Publications.	Administration.	Total.
1902	....	....	$4,500.00	....	$27,513.00	$32,013.00
1903	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	437,941.40	73,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	463,609.75	63,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171,59	43,552.89	1,571,572.60
Total..	1,811,068.37	4,265,298.27	1,174,577.87	416,030.52	504,322.41	8,171,297.44

Investments in Property. On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments the following sums have been expended:

Schedule of real estate, equipments, and publications.

Administration: Building, site, and equipment		$330,236.07
Publications:		
Stock on hand (Oct. 31, 1913)	$218,268.95	
Outstanding accounts (Oct. 31, 1913)	2,006.88	
		220,275.83
Department of Botanical Research (Sept. 30, 1913):		
Buildings, office, and operating	39,913.78	
Laboratory equipment	8,410.56	
		48,324.34
Department of Experimental Evolution (Sept. 30, 1913):		
Buildings, office, and library	47,104.29	
Laboratory apparatus	5,821.83	
Operating appliances and grounds	17,459.91	
		70,386.03
Geophysical Laboratory (Sept. 30, 1913):		
Building, library, operating appliances	117,852.52	
Laboratory apparatus	66,007.82	
Shop equipment	14,062.91	
		197,923.25
Department of Historical Research (Sept. 30, 1913):		
Office	1,576.57	
Library	2,533.06	
		4,109.63
Department of Marine Biology (June 30, 1913):		
Vessels	32,325.40	
Buildings, docks, furniture, and library	11,017.21	
Apparatus and instruments	4,183.10	
		47,525.71
Department of Meridian Astrometry (April 30, 1913):		
Apparatus and instruments		2,394.34
Nutrition Laboratory (Sept. 30, 1913):		
Building, office, and shop	114,139.99	
Laboratory apparatus	15,627.78	
		129,767.77
Solar Observatory (Aug. 31, 1913):		
Buildings, grounds, road, and telephone line	194,904.12	
Shop equipment	34,989.84	
Instruments	355,309.89	
Furniture and operative appliances	76,858.34	
Hooker 100-inch reflector	92,017.78	
		754,079.97
Department of Terrestrial Magnetism (Sept. 30, 1913):		
Office	6,118.77	
Instruments	39,427.55	
Vessel and ocean equipment	117,672.66	
Land equipment	1,326.35	
		164,545.33
		1,919,568.27

PUBLICATIONS.

Publications Authorized and Issued During the Year.

The publication of twenty-five volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of $66,639.30. The following list gives the titles and names of the authors of the publications issued during the year; it includes 29 volumes, with an aggregate of 6,605 octavo pages and 2,752 quarto pages. Thirty additional volumes are now in press.

List of publications issued during the year.

Year Book, No. 11, 1912. Octavo, XVI+294 pages, 7 plates.
Index Medicus, Second Series, vol. 10, 1912. Octavo, 1,511 pages.
No. 54. Willis, Bailey, Charles D. Walcott, and others. Research in China, in three volumes and atlas. Vol. 3. Paleontology. Quarto, 375 pages, 29 plates, 9 figures.
 The Cambrian Faunas of China, pp. 1–276, 24 pls., 9 figs.; by C. D. Walcott.
 A Report on Ordovician Fossils collected in Eastern Asia in 1903–04, pp. 277–294, 2 plates; by Stuart Weller.
 A Report upon Upper Paleozoic Fossils collected in China in 1903–04, pp. 295–334, 3 plates; by George H. Girty.
No. 74. Sommer, H. Oskar. Vulgate Version of the Arthurian Romances: Edited from MSS. in the British Museum. Quarto.
 Vol. VI. Les Aventures ou La Queste del Saint Graal. La Mort le Roy Artus. 388 pages.
 Vol. VII. Supplement: Le Livre d'Artus, with Glossary. MS. No. 337, Bibliothèque Nationale. 370 pages.
No. 90A. Andrews, Charles M. Guide to the Materials for American History, to 1783, in the Public Records Office of Great Britain. Octavo, two volumes.
 Vol. I. The State Papers, XI+346 pages.
No. 159. Howard, L. O., Harrison G. Dyar, and Frederick Knab. The Mosquitoes of North and Central America and the West Indies. In 4 volumes, octavo.
 Vol. I. A General Consideration of Mosquitoes, their Habits and their Relations to the Human Species. VII+520 pages, 14 plates, 6 figures.
 Vol. II. X pages, 150 plates.
No. 163. Bolton, Herbert E. Guide to Materials for the History of the United States in the Principal Archives of Mexico. Octavo, XV+553 pages.
No. 168. Burnham, S. W. Measures of Proper Motion Stars. Quarto, IV+311 pages.
No. 169. Callaway, Morgan. The Infinitive in Anglo-Saxon. Octavo, XIII+339 pp.
No. 171. Lancaster, H. C. Pierre Du Ryer, Dramatist. Octavo, V+182 pages, 1 pl.
No. 172. Parker, David W. Guide to the Materials for United States History in Canadian Archives. Octavo, X+339 pages.
No. 173. Reichert, Edward T. The Differentiation and Specificity of Starches in relation to Genera, Species, etc. Stereochemistry applied to Protoplasmic Processes and Products, and as a strictly Scientific Basis for the Classification of Plants and Animals. Quarto, in two parts.
 Part I. The Starch-Substance and Starch-Grain. Pages I–XVII+1–342, 102 plates containing 612 photomicrographs, charts A–J.
 Part II. The Differentiation and Specificity of Starches. Pages I–XVII+343–900 and 400 charts.
No. 175. Bauer, L. A. Land Magnetic Observations, 1905–1910. (Researches of the Department of Terrestrial Magnetism.) Quarto, IV+185 pages, 10 plates.
No. 176. Benedict, Francis G., and Elliott P. Joslin. A Study of Metabolism in Severe Diabetes. Octavo, VI+135 pages, 1 text figure.
No. 177. Loeb, Leo, in collaboration with Carl L. Alsberg, Elizabeth Cooke, Ellen P. Corson-White, Moyer S. Fleisher, Henry Fox, T. S. Githens, Samuel Leopold, M. K. Meyers, M. E. Rehfuss, D. Rivas, and Lucius Tuttle. The Venom of Heloderma. Octavo, VI+244 pages, 38 figures.
No. 178. Cannon, W. A. Botanical Features of the Algerian Sahara. Octavo, VI+81 pages, 37 plates.

No. 179. Castle, W. E., and C. C. Little. Reversion in Guinea-pigs and its Explanation (Paper No. 18, Station for Experimental Evolution.) By W. E. Castle. Octavo, 10 pages.
Experimental Studies of the Inheritance of Color in Mice. (Paper No. 19, Station for Experimental Evolution.) By C. C. Little. Octavo, 92 pages, 5 colored plates.
No. 180. Jones, Harry C., and Collaborators. The Freezing-point Lowering, Conductivity, and Viscosity of Solutions of Certain Electrolytes in Water, Methyl Alcohol, Ethyl Alcohol, Acetone, and Glycerol, and in Mixtures of these Solvents with One Another. Octavo, vii+214 pages, 85 text figures.
No. 181. Case, E. C., S. W. Williston, and M. G. Mehl. Permo-Carboniferous Vertebrates from New Mexico. Quarto, v+81 pages, 1 plate, 51 figures.
No. 186. Barus, Carl. The Diffusion of Gases through Liquids, and Allied Experiments. Octavo, vi+88 pages, 38 text figures.
No. 188. Davenport, Charles B. Heredity of Skin-Color in Negro-White Crosses. (Paper No 20, Station for Experimental Evolution.) Octavo, 106 pages, 4 plates.
No. 190. Jones, Harry C., and J. S. Guy. Absorption Spectra of Solutions as Affected by Temperature and by Dilution: A Quantitative Study of Absorption Spectra by means of the Radiomicrometer. Octavo, vii+93 pages, 22 plates, 44 text figures.
Classics of International Law:
Ayala, Balthazar: De Jure et Officiis Bellicis et Disciplina Militari. Edited by John Westlake. 2 vols.
Vol. I. A Reproduction of the edition of 1582, with portrait of Ayala, Introduction by Professor Westlake, etc. Pages xxvii+226.
Vol. II. Translation of the Text, by John Pawley Bate. Pages xvi+250.
Grotius, Hugo. De Jure Belli ac Pacis Libri Tres, in quibus Jus Naturae & Gentium, item Juris Publici Præcipua explicantur.
Vol. I. Reproduction of the edition of 1646. Octavo, 618+45 pages.
Reports upon the Present Condition and Future Needs of the Science of Anthropology. By W. H. R. Rivers, A. E. Jenks, and S. G. Morley. Quarto, 91 pages, 14 plates.

Sales of Publications and Value of Those on Hand.

The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903	$2,256.91	$29.25	....
1904	2,370.47	52.85	$12.75
1905	2,562.76	44.75	431.44
1906	2,970.56	37.60	1341.52
1907	3,676.71	56.50	2,292.89
1908	3,406.19	99.65	4,371.67
1909	4,821.85	73.01	6,287.21
1910	4,470.50	100.70	5,899.05
1911	4,440.21	85.50	6,366.55
1912	4,652.14	61.65	6,782.34
1913	4,992.02	75.95	7,140.69
Total...	40,620.32	717.41	40,926.11

At the end of the fiscal year just closed there are on hand 87,227 volumes of miscellaneous publications and Year Books, having a sale value of $204,443.45. There are also on hand 28,543 numbers, or

the equivalent of about 2,200 volumes, of the Index Medicus, having a sale value of $13,825.50. The total value of publications on hand is therefore $218,268.95.

In connection with the above statement it is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales, a total of 117,762 volumes of publications of the Institution.

Of statistical interest in respect to the work of publication of the Institution the data furnished in the following table are instructive.

Growth and Extent of Institution's Publications.

Two hundred and fifty-nine volumes, embracing a total of upwards of 67,000 pages of printed matter, have thus far been issued by the Institution. The maximum number of volumes and the maximum number of pages for any one year were attained in 1907 by reason of a gradual accumulation of manuscripts for publication up to that time. Since then the number of volumes issued per year has varied from 19 to 30, with an average of 26 volumes.

Table showing number of volumes, number of pages (octavo and quarto), and total number of pages of publications issued by the Institution for each year and for the twelve years since 1902.

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902.......	4	397	....	397
1903.......	4	1,732	....	1,732
1904.......	15	3,297	169	3,466
1905.......	21	3,783	1,445	5,228
1906.......	19	3,166	1,288	4,454
1907.......	38	6,284	3,428	9,712
1908.......	28	4,843	2,485	7,328
1909.......	19	3,695	1,212	4,907
1910.......	30	3,274	4,831	8,105
1911.......	30	5,062	1,670	6,732
1912.......	23	3,981	2,044	6,025
1913.......	29	6,605	2,752	9,357
Total...	260	46,119	21,324	67,443

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication, and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the year 1912–1913.

During the fiscal year ending October 31, 1913, the Executive Committee held nine meetings. Printed reports of these meetings have been sent to the Trustees of the Institution.

Upon the adjournment of the Board of Trustees on December 13, 1912, the members of the Executive Committee met and organized by the election of Mr. Welch as Chairman for 1913, and by voting that the Assistant Secretary of the Institution act as Secretary of the Committee for the same period.

It becomes the duty of the Executive Committee to report the death, on March 11, 1913, of John Shaw Billings, a member of the Committee since the foundation of the Institution and Chairman of the Board of Trustees since December 1903, and to record the following resolution passed by the Committee at its meeting of March 21, 1913:

Resolved, That the Executive Committee of the Carnegie Institution of Washington record an expression of its keen personal and official regret and sense of loss upon the death of Dr. John S. Billings. Dr. Billings has long been Chairman of the Board of Trustees of the Institution. He was one of the organizers of the Institution and one of those who before the organization inspired and guided the development of the project. He has been a member of the Executive Committee from the beginning. He has been assiduous and devoted to the duties of his trust. His breadth of learning and of interest in all departments of knowledge, his sturdy and fearless independence of character and the safe-guarding influence of his experience have been of inestimable value during the experimental and formative period of the Institution, of whose future usefulness his service will be one of the chief foundations.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1912–1913, together with itemized financial statements for the same period and a summary of receipts

and expenditures of the Institution to date. The President also submits various recommendations and suggestions and an outline of suggested appropriations for the year 1914. The Executive Committee hereby approves the report of the President and his recommendations as the report and recommendations of the Committee.

The Board of Trustees at its meeting of December 13, 1912, appointed the American Audit Company to audit the accounts of the Institution for the fiscal year ending October 31, 1913, and the report of this company is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a balance sheet, showing the condition of the assets and liabilities of the Institution on October 31, 1913, together with statements of receipts and disbursements for the fiscal year and of aggregate receipts and disbursements since the organization of the Institution on January 28, 1902.

Two vacancies in the Board of Trustees, occasioned by the death of Mr. Billings and by the resignation of Mr. Gage, will call for action at the coming annual meeting of the Trustees.

The position of Chairman of the Board of Trustees has been rendered vacant by reason of the death of Mr. Billings.

William H. Welch, *Chairman.*
Cleveland H. Dodge.
S. Weir Mitchell.
Wm. Barclay Parsons.
Elihu Root.
Charles D. Walcott.
Robert S. Woodward.

November 20, 1913.

Balance Sheet, October 31, 1913.

ASSETS.		
Investments:		
Securities (page 44)		$22,894,579.17
Property Account:		
Real estate, equipments, and publications (page 45)		1,969,568.27
Current Assets:		
Cash (page 42)	$509,278.10	
Stamps and petty cash	300.00	
Income receivable (1913)	114,115.37	
		623,693.47
		25,487,840.91

LIABILITIES.		
Endowment Fund:		
Endowment	$22,000,000.00	
Profit from redemption of bonds	45,000.00	
		$22,045,000.00
Sundry Reserve Funds:		
Reserve Fund	784,349.49	
Insurance Fund	81,960.12	
		866,309.61
Invested in Property		1,969,568.27
Current Liabilities:		
Large grants	307,965.70	
Minor grants	45,903.53	
Publication	95,739.59	
Administration	19,733.32	
		469,342.14
Unappropriated Fund		137,620.89
		25,487,840.91

Receipts and Disbursements from November 1, 1912, to October 31, 1913.

RECEIPTS.

INTEREST FROM—		
Endowment—		
Bonds	$1,103,355.00	
Bank balance	18,010.44	
		$1,121,365.44
Reserve Fund—		
Bonds	25,135.00	
Bank balance	471.67	
		25,606.67
Insurance Fund—		
Bonds	2,652.50	
Bank balance	45.99	
		2,698.49
SALES OF PUBLICATIONS:		
Index Medicus	4,992.02	
Year Book	75.95	
Pamphlets	6.01	
Miscellaneous books	7,134.68	
		12,208.66
REFUND ON GRANTS:		
Grant No. 797	12.55	
749	125.00	
746	.49	
861	2,500.00	
818	45.71	
866	66.00	
862	400.00	
874	77.78	
		3,227.53
MISCELLANEOUS:		
Executive Committee	25.00	
Shipping	196.06	
Office expenses	11.77	
Building	22.55	
Printing and paper	514.57	
		769.95
REDEMPTION OF BONDS:		
U. S. Steel Corporation		345,000.00
		1,510,876.74
Balance from last report to Trustees, October 31, 1912		569,973.96
		2,080,850.70

DISBURSEMENTS.

INVESTMENT:		
Bonds		$666,428.03
GRANTS:		
Large	$698,337.03	
Minor	110,083.06	
		808,420.09
PUBLICATION		53,171.59
ADMINISTRATION:		
Trustees	3,272.04	
Executive Committee	1,580.31	
Salaries	25,840.00	
Publication—shipping expenses	4,551.03	
Sureties, rent, telephone	406.22	
Equipment	1,159.47	
Stationery	250.16	
Postage, express, telegrams, and exchange	447.13	
Printing (including Year Book for 1912)	2,698.38	
Office supplies and petty expenses	1,132.45	
Building and grounds—		
Supplies and janitor service	1,983.64	
Fuel, light, water	232.06	
		43,552.89
		1,571,572.60
CASH ON DEPOSIT:		
U. S. Trust Co. of New York—		
Drawing account	483,739.52	
Endowment fund	496.70	
Reserve fund	14,302.87	
Insurance	1,930.87	
National City Bank of New York	6,153.01	
Am. Security and Trust Co., D. C.	2,655.13	
	509,278.10	
		2,080,850.70

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1913.

RECEIPTS.

INTEREST:		
Endowment bonds	$7,678,355.00	
Reserve Fund bonds	40,203.75	
Insurance Fund bonds	4,652.50	
Income and Building Fund bonds	94,005.56	
Deposits in banks	110,800.00	
		$7,928,016.81
SALES OF PUBLICATIONS:		
Index Medicus	40,620.32	
Year Book	717.41	
Miscellaneous	40,926.11	
		82,263.84
REFUND ON GRANTS		19,123.51
MISCELLANEOUS:		
Organization	1,825.52	
Sale of furniture	69.00	
Gas deposit	5.36	
Postage, express, and travel	56.65	
Printing and paper	3,121.92	
Sale of metal cuts	61.80	
separates	213.77	
Refund, shipping	375.36	
grounds	38.46	
office	59.43	
insurance	4,717.00	
operating	18.00	
telephone and light	29.53	
trustees	32.03	
building	22.55	
Executive Committee	25.00	
		10,671.38
REDEMPTION AND SALE OF BONDS:		
U. S. Steel Corporation	345,000.00	
Northern Pacific-Great Northern	48,000.00	
Northern Pacific	102,750.00	
Atchison, Topeka and Santa Fe	49,500.00	
Lake Shore and Michigan Southern	47,000.00	
Central Pacific	48,250.00	
		640,500.00
		8,680,575.54

DISBURSEMENTS.

INVESTMENT:		
Bonds	$1,501,152.68	
Administration building and site	309,915.69	
		$1,811,068.37
GRANTS:		
Large	4,265,298.27	
Minor	1,174,577.87	
		5,439,876.14
PUBLICATION		416,030.52
ADMINISTRATION:		
Trustees	25,685.14	
Executive Committee	19,102.46	
Honorariums to advisers	17,319.81	
Salaries	301,328.03	
Publication—shipping expenses	16,356.31	
Rent, surety, telephone	29,234.16	
Equipment	13,076.48	
Stationery	12,218.15	
Postage, express, telegrams, and exchange	19,467.37	
Printing (including Year Books)	28,140.88	
Office expenses	3,270.99	
Building and grounds—		
Supplies and janitor service	8,478.06	
Fuel, light, water	2,919.52	
Organization	1,825.52	
Plans and option	5,166.46	
Seal	555.60	
Miscellaneous	70.23	
		504,215.17
REFUND:		
Publication	20.25	
Index Medicus	86.99	
		107.24
		8,171,297.44
CASH IN BANKS (page 42)		509,278.10
		8,680,575.54

Schedule of Securities.

Par value.	Securities.	Investment value.	Total.
	ENDOWMENT.		
$10,000,000	U. S. Steel Corporation, Series B, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	$10,000,000.00	
1,700,000	U. S. Steel Corporation, Series A, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	1,700,000.00	
2,500,000	U. S. Steel Corporation, Series C, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	2,500,000.00	
2,500,000	U. S. Steel Corporation, Series D, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	2,500,000.00	
2,500,000	U. S. Steel Corporation, Series E, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	2,500,000.00	
2,500,000	U. S. Steel Corporation, Series F, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	2,500,000.00	
13,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ p. ct. gold bonds, due May 1, 1989	12,935.00	
325,000	Lehigh & Lake Erie Railroad Co., first mortgage, 4½ per cent bonds, due 1957	331,568.30	
			$22,044,503.30
	INSURANCE FUND.		
28,000	American Telephone and Telegraph Co., 4½ per cent convertible bonds	28,978.00	
50,000	Atchison, Topeka & Sante Fe Railway Co., general mortgage, 100-year, 4 per cent registered gold bonds, due 1995	50,056.25	
1,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ p. ct. gold bonds, due May 1, 1989	995.00	
			80,029.25
	RESERVE FUND.		
50,000	American Telephone and Telegraph Co., collateral trust 4 per cent bonds, due 1929	45,500.00	
96,000	American Telephone and Telegraph Co., 4½ per cent convertible bonds	99,456.25	
50,000	Central Pacific Rwy. Co., first refunding mortgage 4 p. ct. registered gold bonds, due 1949	48,250.00	
15,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ p. ct. gold bonds, due May 1, 1989	14,925.00	
15,000	Great Northern Railway Co., first and refunding mortgage 4¼ per cent bonds, due 1961	15,227.00	
155,000	General Electric 5 per cent gold debenture bonds	158,213.47	
150,000	Interborough Rapid Transit Co., first refunding mortgage 5 per cent bonds, due 1966	147,751.00	
50,000	Lake Shore & Michigan Southern Railway Co., registered 25-year 4 per cent gold bonds, due September 1, 1928	47,000.00	
50,000	Long Island Railroad Co., refunding mortgage 4 per cent bonds, due 1949	48,285.00	
50,000	New York, Westchester & Boston Railway Co., first mortgage 4½ per cent bonds, due 1946	49,187.50	
50,000	Northern Pacific-Great Northern (Chicago, Burlington & Quincy collateral), joint 4 per cent bonds, due 1921	49,876.40	
50,000	Oregon-Washington R. R. & Navigation Co., first and refunding 4 p. ct. mortgage bonds, due 1961	46,375.00	
			770,046.62
22,898,000			22,894,579.17

Schedule of Real Estate, Equipment, and Publications.

ADMINISTRATION:		
Building, site, and equipment		$330,236.07
PUBLICATIONS:		
Stock on hand (Oct. 31, 1913)	$218,268.95	
Outstanding accounts (Oct. 31, 1913)	2,006.88	
		220,275.83
DEPARTMENT OF BOTANICAL RESEARCH (SEPT. 30, 1913):		
Buildings, office, and operating	39,913.78	
Laboratory equipment	8,410.56	
		48,324.34
DEPARTMENT OF EXPERIMENTAL EVOLUTION (SEPT. 30, 1913):		
Buildings, office, and library	47,104.29	
Laboratory apparatus	5,821.83	
Operating appliances and grounds	17,459.91	
		70,386.03
GEOPHYSICAL LABORATORY (SEPT. 30, 1913):		
Building, library, operating appliances	117,852.52	
Laboratory apparatus	66,007.82	
Shop equipment	14,062.91	
		197,923.25
DEPARTMENT OF HISTORICAL RESEARCH (SEPT. 30, 1913):		
Office	1,576.57	
Library	2,533.06	
		4,109.63
DEPARTMENT OF MARINE BIOLOGY (JUNE 30, 1913):		
Vessels	32,325.40	
Buildings, docks, furniture, and library	11,017.21	
Apparatus and instruments	4,183.10	
		47,525.71
DEPARTMENT OF MERIDIAN ASTROMETRY (APR. 30, 1913):		
Apparatus and instruments		2,394.34
NUTRITION LABORATORY (SEPT. 30, 1913):		
Building, office, and shop	114,139.99	
Laboratory apparatus	15,627.78	
		129,767.77
SOLAR OBSERVATORY (AUG. 31, 1913):		
Buildings, grounds, road, and telephone line	194,904.12	
Shop equipment	34,989.84	
Instruments	355,309.89	
Furniture and operative appliances	76,858.34	
Hooker 100-inch reflector	92,017.78	
		754,079.97
DEPARTMENT OF TERRESTRIAL MAGNETISM (SEPT. 30, 1913):		
Office	6,118.77	
Instruments	39,427.55	
Vessel and ocean equipment	117,672.66	
Land equipment	1,326.35	
		164,545.33
		1,969,568.27

REPORT OF AUDITOR.

WASHINGTON, D. C., *November 21, 1913.*

The Executive Committee, Carnegie Institution of Washington:

GENTLEMEN: The books and accounts of the Carnegie Institution of Washington have been audited by us from November 1, 1912, to October 31, 1913, by authority of the Board of Trustees. We did not, however, audit the books of the various departments, as that is done by the Bursar and his associates, but we did verify the totals as carried from the subsidiary books to the general books.

The income from the investments of the Endowment, Reserve, and Insurance Funds, and other sources has been duly accounted for and expenditures have been authorized and are supported by proper vouchers.

The securities representing the Endowment, Reserve, and Insurance Funds were produced to us, the cash in hand was verified by count, and the cash on deposit with banks was verified by properly authenticated certificates.

Respectfully submitted.

THE AMERICAN AUDIT COMPANY,
By OTTO LUEBKERT, *Resident Vice-President.*

Approved:
F. W. LAFRENTZ, *President.*

[Seal of the American Audit Company, New York.]

Attest:
A. F. LAFRENTZ, *Assistant Secretary.*

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK ACCOMPLISHED DURING FISCAL YEAR BY GRANTEES AND ASSOCIATES.

Under this heading it is sought to include titles of all publications bearing upon work done under grants from the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 33–34). The following list has been made as complete as possible, and in some cases titles may be included which have only an indirect connection with grants from the Institution.

Adams, F. D. An experimental investigation into the flow of rocks. (Extrait du Compte Rendu du xie Congrès Geologique International.)

Adams, L. H. A useful type of formula for the interpolation and representation of experimental results. (Jour. Wash. Acad. Sci., vol. 3, pp. 469–474. 1913.)

———. See Johnston, John.

Adams, Walter S. Stellar spectroscopic results. (Read at 15th meeting Astron. and Astrophys. Soc. of America.)

———, and Henry G. Gale. On the pressure shift of iron lines. (Astrophys. Jour. June 1913.)

———, and Jennie B. Lasby. The later spectrum of *Nova Geminorum* No. 2. (Monthly notices, R. A. S., vol. 73, No. 9. 1913.)

———, and A. van Maanen. A group of stars of common motion in the h and χ Persei clusters. (Astron. Jour., vol. 27, No. 24. 1913.)

Ault, J. P., and W. F. Wallis. Halley's observations of the magnetic declination, 1698–1700. (Terr. Mag., vol. 18, No. 3, pp. 126–132. Sept. 1913.)

Banta, A. M. Selection within pure lines in *Daphnia*. (Science, n. s., vol. 37, No. 946, p. 272. Feb. 14, 1913.)

———. Experiments on the light and tactile reactions of a cave variety and an open-water variety of an amphipod species. (Proc. Soc. Exp. Biol. and Med., vol. 10, No. 5, p. 192. May 21, 1913.)

———, and R. A. Gortner. Induced modifications in pigment development in *Spelerpes* larvæ. (Preliminary paper presented at annual meeting of Ohio Academy of Science, Columbus, Nov. 30, 1912. Ohio Nat., vol. 13, No. 3, pp. 49–55. Jan. 1913.)

———, ———. Certain observations on the occurrence of tyrosinase in amphibian egg jell. (Proc. Soc. Exp. Biol. and Med., vol. 10, No. 5, p. 191. May 21, 1913.)

Barcroft, J., G. Graham, and H. L. Higgins. The effect of carbohydrate-free diet on the dissociation curve of blood. (Preliminary communication. Proc. Physiol. Soc. Jan. 18, 1913. Jour. Physiol., vol. 15, p. xlvii. 1913.)

Bartsch, Paul. Observations in mollusks among the Bahama Islands and the Florida Keys. (Smithson. Misc. Coll., vol. 60, pp. 58–62. 1913.)

Barus, Carl. Diffusion of air and other gases through water. (British Assoc. Report, extract only, Portsmouth meeting.)

———, The indices of doubly refracting crystals. (Phil. Mag., vol. xxiv, p. 827. 1913.)

———. A simple screw micrometer. (Amer. Jour. Sci., vol. xxxv, p. 267. 1913.)

———. Growth of air bubbles on the walls of a beaker, etc. (Amer. Jour. Sci., vol. xxxiv, p. 304. 1912.)

———. Resolution of interference fringes. (Amer. Jour. Sci., vol. xxxv, pp. 308–310. 1913.)

———. Interferometry of air carrying electrical current. (Amer. Jour. Sci., vol. xxxiv, pp. 101–106. 1912.)

———. Viscosity of gases and Bunsen flame. (Science, vol. xxxvi, p. 320. 1912.)

Bauer, L. A. On the cause of the Earth's magnetic field. (Address delivered before the Astron. and Astrophys. Soc. of America, Aug. 27–31, 1912. Abstr. Science, vol. 37, No. 940. pp. 27–28. Jan. 3, 1913.)

———. A consistent theory of the origin of the Earth's magnetic field. (Presented before Philosophical Society of Wash., Dec. 7, 1912. Jour. Wash. Acad. Sci., vol. 3, No. 1, pp. 1–7. Jan. 4, 1913.)

———. On the origin of the Earth's magnetic field. (Presented before Amer. Phys. Soc. and Section B of the A. A. A. S., Cleveland. Dec. 30, 1912. Phys. Rev., n. s. vol. 1, No. 3, pp. 254–257. Mar. 1913.)

———. Magnetic results of Halley's expedition, 1698–1700. (Terr. Mag., vol. 18, No. 3, pp. 113–125. Sept. 1913.)

———. Gegenwärtiger Stand der magnetischen Vermessung der Erde durch die Carnegie Institution of Washington. (Repr. Zeit. der Ges. für Erd. zu Berlin, No. 6. 1913.)

Bauer, L. A. The Earth's magnetism. (Fourth Halley Lecture delivered at University of Oxford. May 22, 1913. Bedrock. Oct. 1913.)
———. The magnetic survey of the oceans. (Lecture before Royal Geograph. Soc. London. June 4, 1913. Geograph. Jour. 1913.)
———, and J. A. Fleming. The C. I. W. deflector in use on the *Carnegie* for determining the magnetic horizontal intensity and the magnetic declination at sea. (Terr. Mag., vol. 18, No. 2, pp. 57–62. June 1912.)
———, and W. J. Peters. Magnetic declinations and chart corrections obtained by the *Carnegie* from Suva, Fiji, to Papeete, July to Sept. 1912, and from Papeete, Tahiti, to Port Stanley, Falkland Islands, Oct. 1912 to Jan. 1913. (Terr. Mag., vol. 17, No. 4, pp. 179–180; vol. 18, No. 2, pp. 63–64. Dec. 1912; June 1913.)
———, ———. Magnetic declinations and chart corrections obtained by the *Carnegie* from Port Stanley, Falkland Islands, to St. Helena and Bahia, Feb. to Apr. 1913. (Terr. Mag., vol. 18, No. 3, pp. 111–112. Sept. 1913.)
Benedict, Francis G. The influence of the ingestion of food upon metabolism. (Trans. Fifteenth Internat. Cong. on Hygiene and Demography. Sept. 1912.)
———. Der Einfluss der Nahrungsaufnahme auf den Stoffwechsel. (Deutsch. Archiv f. klin. Med., vol. 110, p. 154. 1913.)
———, and Elliott P. Joslin. Ueber den Stoff- und Energieumsatz bei Diabetes. (Deutsch. Archiv f. klin. Med., vol. 111, p. 333. 1913.)
———, and Joseph H. Pratt. The metabolism after meat feeding of dogs in which pancreatic external secretion was absent. (Jour. Biol. Chem., vol. 15, p. 1. 1913.)
———. See Cady, W. G.
Bjerknes, V. Die Meteorologie als Exakte Wissenschaft. (Braunschweig, Druck und Verlag von Friedr. Vieweg & Sohn. 1913.)
———. Das CGS-System und die Meteorologie. (Separat-Abdruck aus der Meteorologischen Zeitschrift, Heft 2. 1913.)
Blakeslee, A. F. Tree study in winter. (Nature Study Rev., pp. 13–21, Jan. 1913.)
———. A labeling surface for laboratory glassware. (Science, vol. xxxvii, pp. 561–562. Apr. 11, 1913.)
———. Conjugation in the heterogamic genus *Zygorrhynchus*. (Mycologisches Centralblatt, Bd. ii, pp. 241–244. Apr. 1913.)
———. Field work on trees. (Nature Study Rev., pp. 121–125. May 1913.)
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REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1913, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.*

D. T. MacDougal, Director.

The development of the researches carried out under the auspices of the Department has resulted in a concentration of the attention of the members of the staff and collaborators upon problems in photo-chemistry, especially phyto-chemistry, and in the environic reactions of organisms with especial reference to light, temperature, and moisture, and also to the correlation of such physical and physiological results with geographic occurrence, distributional movements, and genetics of organisms.

Such progress has been made in the first-named subject that it is now possible to formulate definite methods looking toward the determination of the actual manner in which the energy of light acts upon living matter, not only in the chlorophyll processes, but in its other probable ionization effects. A small laboratory especially fitted for such work has been planned, which will furnish adequate facilities for the extension of the preliminary results.

Some additional results on the relation of plants to climatic complexes secured from the experimental cultures in the montane plantation and at the coastal laboratory have made available certain qualitative data upon the basis of which a factorial laboratory may be planned with a high degree of promise as to its efficiency and importance of results, and the next opportunity for increasing the equipment of the Department will be devoted to the organization of facilities of this character. Adequate power for furnishing heat, refrigeration, light, pressure, and moisture-control under conditions as exactly regulated as those of a bacteriological thermostat in chambers large enough for plants of full size during their entire development would be the main feature of a laboratory of this kind. The construction would include such specialties as the substitution of quartz for glass and devices for the calibration of intake and outgo analogous to those necessary in the operation of a respiration calorimeter. These facilities would enable the researcher to analyze or totalize the effect of any one of the single factors which make up "environment" and test the behavior of organisms with reference to their previous individual experience or genetic history. Definite advance in some of the main problems of physiology must await the organization of such equipment, which at present does not exist.

*Situated at Tucson, Arizona. Grant No. 859. $38,005 for investigations and maintenance during 1913. (For previous reports see Year Books Nos. 2–11.)

Members of the staff, research associates, and other persons collaborated under the auspices of the Department during the year, in the field, in the laboratories of the Department, and in various institutions. Field-work has been carried out in the West Indies and in southern California and Arizona for the purpose of studying the distribution of the cacti and of making various observations relative to the problems of the Salton Sea and other geographical researches.

THE SALTON SEA.

The Salton Sea: A Study of the Geography, Geology, Floristics, and Ecology of a Desert Basin.

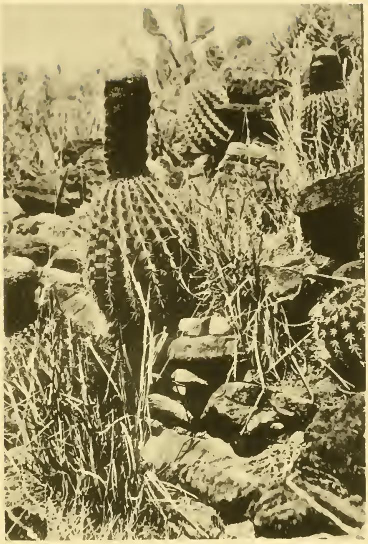
The comprehensive observations which were begun on the Salton Sea at the time of its maximum level in 1907 have now been brought to a stage where the results seem worthy of compilation and presentation, and a manuscript with the above title has been presented to the Institution and is scheduled to appear as Publication No. 193. Summaries of the newer or more important results are given under the headings below. As may be seen, while definitely organized work on the subject was begun but seven years ago, the original expedition to the basin was made by Professor Blake in 1853, and Dr. MacDougal spent some time in the basin in 1903, 1905, and 1906.

The Cahuilla Basin and the Desert of the Colorado, by W. P. Blake (deceased).

Concerning the discovery of the true nature of the Cahuilla Basin and of the passage into it from the westward, Professor Blake wrote:

> To one of the expeditions of 1853 was assigned the duty of following the Sierra Nevada of California southward, to seek for any suitable pass through which a railway might be built. This survey was placed in charge of Lieut. R. S. Williamson, of the U. S. Topographical Engineers, with Lieut. J. G. Parke second in command, and the writer as geologist. Walker Pass, much vaunted at the time as the best and only practicable pass in the Sierra Nevada, was the first objective point. It was most favored by Senator Gwin of California (known also as "Duke Gwin") who had personally taken the field and journeyed as far south as the Tejon, and could see from its summit a favorable route across the Great Basin eastward. Surveys were made by the Williamson expedition of Walker's Pass, the Taheechapah (the orthography of which has been corrupted to Tehachipi), Tejon, Cañada de las Uvas, the passes north of Los Angeles, and the Cajon from the Mojave to San Bernardino, without finding any pass that offered an especially favorable and easy route or inviting grades.
>
> Imagine, then, the enthusiasm with which the unknown great break in the mountain range between San Bernardino and San Jacinto was approached by the members of the party as we made our way eastward from the region, then practically unoccupied, but now known as Colton and Redlands, and found an easy grade and open country for our train of wagons to the summit, only 2,580 feet above the sea. Here, at last, was discovered the greatest break through the western cordillera leading from the slopes of Los Angeles and the Pacific into the interior wilderness. It had no place upon the maps,

A 

 B

 C

A. Cephalocereus, St. Christopher, British West Indies.

B. Cactus anchored in rocks on shore facing the sea, St. Christopher, British West Indies.

C. Scene from Desert Region at Azua, Dominican Republic. The large plant in the center represents a type of Opuntia known only from the West Indies.

and had not been traversed by surveying parties or wagons. From the summit we could look eastward and southward into a deep and apparently interminable valley stretching off in the direction of the Gulf of California. This pass was evidently the true gateway from the interior to the Pacific Ocean. The discovery of this practicable and easy railway route determined the construction of a southern railroad, and made it necessary to acquire from Mexico the strip of country in southern Arizona since known as the "Gadsden Purchase."

We descended with eagerness into this great unknown valley, carefully reading the barometer at regular distances to ascertain the grade. Proceeding without obstacles, but without any trace of a road, and following the dry bed of a stream, now known as the Whitewater, we reached the bed of a former lake and found it to be below the level of the sea.

The accumulation of salt in the lowest part of the desert was well known to the Cahuilla Indians, who had resorted to it for salt for an unknown period. Being a little off the trail or road then traveled from Yuma to the settlements in California, it was not often visited or seen by the early explorers, who, after the long journey of 90 miles without water, pressed forward without delay to the shades and springs of potable water on the seaward slope of the mountains at Warner's Ranch.

Emory, 1848, mentions the salt lake as three-quarters of a mile long and half a mile wide, and that the water had receded to a foot in depth. The salt-bed was not conspicuous in 1853, at the time of Williamson's survey. Its precise position was not ascertained. It was said that it was sometimes flooded with water, which was supposed to have reached it from the overflow of the Colorado, through the channel of New River.

Geographical Features of the Cahuilla Basin, by Godfrey Sykes.

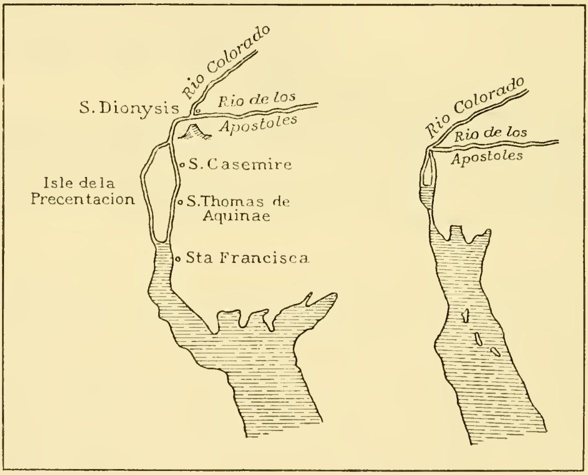
Mr. Sykes has been a member of nearly all of the overland and water expeditions made in the Desert of the Colorado by the force of the Desert Laboratory, and has prepared two sketch maps showing the principal geographic features of interest in connection with the studies of the Cahuilla Basin. Routes and observation stations are located with accuracy. A systematic search has been made in the principal collections of old maps in America and England for records which might suggest changes in the delta of the Colorado and in the Salton Sink in the last 250 years. In addition to the acquisition of valuable information upon the history of exploration of the region, it has been discovered that a map by Rocque (1762?) shows the Colorado River flowing into a body of water to the northwestward of the head of the Gulf of California in the position occupied by the Salton Sink. A similar feature is suggested on other maps of that time.

The Geology of the Cahuilla Basin, by E. E. Free.

This paper summarizes all available information concerning the geology of the Cahuilla region, with especial reference to the history of the lake which previously occupied the basin and which has been named "Blake Sea." The major conclusions are (1) that this lake was fresh, (2) that it was quite recent, and (3) that it was either formed by the Colorado River or greatly modified by the inflow of

that river. Several hypotheses are possible as to the origin of the depression and of the Delta dam which now separates this depression from the sea. These hypotheses are fully discussed, with the conclusion that the present information warrants no final decision between them.

The soils of the basin are divided into two main types—the gravelly and sandy soils of the desert foot-slopes and the silty alluvial soils of the Colorado Delta. Both types are represented on the beaches of the Salton Sea, but neither this distinction nor any other soil property seems to affect the vegetation directly. Indirect effects through moisture relations and the like are occasionally apparent, but usually subordinate to other factors. The occurrence and movements of soil alkali are similarly unimportant ecologically, though some general interest attaches to the fact that submergence in the water of the Salton seems to have had surprisingly little permanent effect upon the alkali content of the soils.



Detail of mouth of Colorado River and head of Gulf of California; from maps by Bonne about 1770.

Origin of Travertine or Tufa Deposits of Salton Sink, by J. C. Jones.

Blake Sea, the body of water which once filled the Salton Sink, left a deposit of calcium carbonate on the rocks bathed by its waters, which is heaviest within a few feet of the maximum level of its waters. The study of these tufas was taken up by Professor Jones for the purpose of elucidating the history of the formation and disappearance of the ancient sea. A consideration of the structure, composition, and

arrangement of the masses of travertine led to the conclusion that their origin may be traced to the action of a complex of bacteria and algæ after the manner of the deposits which are now being formed in the Salton Sea, which have been studied by Professor Brannon (see Annual Report of this Department for 1912). The current theories of Quaternary lakes have been based largely upon a purely chemical interpretation of the tufa deposits. The establishment of the fact that organic agencies have participated will render necessary some revision of ideas concerning the course of existence of such bodies of water as Lake Lahontan. Professor Jones has already carried his work to the lakes representing the remains of this ancient sea and concludes, for example, that Pyramid Lake has not been desiccated since Lahontan was first formed, and that it has taken about 2,000 years to accumulate the salt contained in the present lakes. The continuation of the work will involve a comparison of features in the basin in which Blake Sea formerly occupied the Salton Sink and of the basin in which Lake Lahontan formerly lay.

Seventh Annual Analysis of the Salton Sea Water, by A. E. Vinson.

During 373 days (from June 10, 1912, to June 18, 1913) the total solids in Salton Sea water have increased from 846.55 parts to 1,002.56 parts per 100,000, an increase of 18.4 per cent for the period. When calculated for the year ending June 3, 1913, by the method suggested in the Twenty-second Annual Report, Arizona Agricultural Experiment Station, the annual increase becomes 17.7 per cent (17.5 for the year ending June 3, 1912). The Salton water may now be considered as 1 per cent brine.

	Parts in 100,000		*Parts in 100,000*
Total solids (dried at 110° C.) plus water of occlusion and hydration	1,002.56	Lithium, Li	......
Water of occlusion and hydration	32.6	Chlorine, Cl	473.89
Sodium, Na	323.08	Sulphuric, SO_4	124.65
Potassium, K	3.45	Carbonic, CO_3 in total solids	......
Calcium, Ca	19.75	Carbonic, CO_3 total	11.28
Magnesium, Mg	16.22	Bicarbonic, HCO_3 volumetric	15.94
Aluminum, Al	1.25	Silicic, SiO_4	2.18
Iron, Fe	0.38	Phosphoric, PO_4	Trace.
Manganese, Mn	None.	Nitric, NO_3	None.
Zinc, Zn	None.	Nitrous, NO_2	None.
Lead, Pb	None.	Oxygen consumed	0.110
Copper, Cu	......	Boric acid	Trace.

Calcium, again, shows a marked decrease, having concentrated only 14.5 per cent, and some additional calcium undoubtedly was brought into the sink by drainage. The total carbon dioxide and also the bicarbonic radicle show a less concentration than last year.

The decrease in carbon dioxide is slightly greater than required by the decrease in calcium, as shown by analysis. This is due, probably, to drainage water carrying calcium salts other than bicarbonate.

The most interesting feature brought out by this year's analysis is the rapidly increasing rate at which potassium is disappearing. It became apparent in 1912 that the ratio of potassium to sodium and to total solids was decreasing rapidly, the number of parts per 100,000 in 1912 having remained the same as in 1911. The analysis this year shows less potassium than in 1912, although sodium has increased 19.3 per cent. The ratios of potassium to sodium and to total solids during the seven years that the Salton water has been analyzed is traced in the table herewith.

Year.	Potassium.	Sodium.	Total solids.
1907	1	48.3	158
1908	1	48.3	157
1909	1	49.5	160
1910	1	53.6	171
1911	1	59.8	188
1912	1	71.1	222
1913	1	94.0	288

The Behavior of Micro-organisms in Brines, by G. J. Peirce.

A careful working out by graphs of the distribution of rains and of the one-celled algæ in the brines of the salt-works on the shores of the Bay of San Francisco shows that the behavior of the algæ follows very closely the cycle of the seasons.

Another very significant and suggestive result of this study is the fact that common or table salt is not naturally sterile. Under certain conditions, since it carries its antidote or opposite with it, it may induce such decompositions or other changes in the materials which it is intended and supposed to preserve that they become dangerous as well as undesirable as food. Further studies in this direction should lead to important results, owing to the very general use of salted meats and salted fish as articles of food, and to the belief that certain maladies are connected with the protracted or too exclusive use of salted foods.

Action of Salton Sea Water on Vegetable Tissues, by M. A. Brannon.

The results of Dr. Brannon's studies are given in full in the report of this Department for 1912. While no new facts have been added, the continuance of the hydrolysis effects described by him have been noted and the deposition of calcium observed in his experiments has yielded some new conclusions in connection with the work of Messrs. Free and Jones (see *ante*).

Analysis of the Flora of the Salton Sink, by S. B. Parish.

Of the 156 species of plants found below the high-beach line, 12 are sporophytes and 144 are spermatophytes. The sporophytes are represented by 4 families and 11 genera; the spermatophytes are represented by 37 families (16 of them having but a single species each) and 100 genera (75 of which have but a single species each).

Of the 144 spermatophytes, 113 are indigenous and 31 are introduced. With the exception of a few which have been found on the beaches of Salton Sea, all the introduced plants are confined to those parts of the Sink which have been reclaimed through the economic operations of human settlement; in no case have they been able to intrude where natural conditions remain.

Of the indigenous species of the Sink, 9 are trees, 22 are shrubs, 13 are semishrubs, 23 are perennial herbs, and 46 are annual herbs.

The indigenous spermatophytes may be divided in accordance with their habital character into two classes: (1) those which grow only in water or in moist soil; (2) those which grow in arid soil. The latter constitute the flora of the absolute desert. *Isocoma* and the two species of *Prosopis* are included in the second class, although they grow also in damp soils.

A floral census evidently conveys an inadequate and incorrect presentation of the phyto-geography of a region, if an equal value is given to those species which are widely distributed and abundant and those which are rare, of which, perhaps, the finding of but a single specimen may have rewarded extensive explorations. With this in view an attempt has been made in the table below to segregate those species which are fairly frequent, at least in some parts of the Sink, from those which are rarely seen. In making such a division the tabulator must needs be guided largely by what he has himself observed, so that his results are subject to the revision of other and more extended investigations. Especially does this apply to the annual herbs; for under the irregular meteorological conditions of the Sink an unusual season may bring up in abundance annuals which in ordinary years make hardly any appearance. But it is believed that, on the whole, those species which are indicated in the table as "frequent" are those which the botanist will certainly find, in more or less abundance, not in all but at least in some part of the Sink.

Habital division of the flora.

Ecological classes.	Trees.			Shrubs.			Semishrubs.			Perennial herbs.			Annual herbs.		
	Frequent.	Rare.	Total.	Frequent.	Rare.	Total.	Frequent.	Rare.	Total.	Frequent.	Rare.	Total.	Frequent.	Rare.	Total.
Hydrophytes, etc....	2	1	3	2	5	7	1	3	4	10	5	15	9	2	11
Xerophytes..........	5	1	6	11	4	15	5	4	9	3	6	9	18	15	33
Total............	7	2	9	13	9	22	6	7	13	13	11	24	27	17	44

It appears by the table that of the 72 xerophytes 42 are common in some parts of the Sink. The species which are abundant everywhere in the arid soils of the Sink are but two—*Atriplex canescens*

and *Isocoma veneta* var. *acradenia.* These two are also found in the physiologically dry alkaline soils. In number of individuals they probably equal the united total of all the other plants above the rank of herbs.

The Repopulation of Sterilized Islands, by D. T. MacDougal.

The hills submerged in the formation of the Salton Sea reappeared in the form of islands as the water subsided, leaving a soil with the characters of the ancient beaches encircling the lake, but to which there came only such species as might be carried by currents, winds, or animals. Some species make seeds which float in saline waters unchanged for long periods, and these might be carried across long stretches of water and lodged on the shores. Others, by reason of their small size, might be lifted and carried by the wind after the manner of dust particles; others with extended surfaces presenting wing effects or buoyant structures, such as the pappus of the arrow-weed (*Pluchea*), might also be carried by the wind. Great numbers of birds frequent the shores of the lake and they must be taken into account in any comprehensive consideration of the subject, yet proof was not secured that any single species was carried to an island which might not have reached the place by the operation of the other agencies named. In addition to the above, which have received much attention from geographers, it was found that some of the species concerned in the occupation of the moist beaches have seeds which sink within a few hours or a day of the time they are thrown into the water. Germination ensues quickly in some and the floating seedlings were seen to be capable of endurance of flotation in the water of the lake for periods of a month or more. These would of course begin growth immediately when stranded. Cormorant Island, separated from the shore by a strip of water 6 or 7 miles wide and from a larger island by 2 miles, has been reached by but six species in as many years, four of which are represented by two or three or a few individuals. *Pluchea* and *Baccharis* probably reached the island as wind-borne seeds; *Sesuvium* and *Heliotropium* by flotation of seeds; *Atriplex* by floating seedlings; and *Spirostachys* by birds, although this, as well as *Sesuvium* and *Heliotropium,* have such small seeds that they might have been lifted over the water barrier by winds.

The Occupation of Sterilized Beaches and the Subsequent Changes, by D. T. MacDougal.

The manner and extent to which emersed strands were occupied by plants was found to vary somewhat with the gradient of the slope, the character of the soil, and the nature of the converging slopes. Some species began growth on beaches within a few weeks after the surfaces had been laid bare, while others did not find suitable conditions until two or three years later.

Generally speaking, the alterations consisted in changes from banded or crowded strand-formations (in which the most important agencies affecting the plants were moisture and salt content) to the open desert formations. Species of *Atriplex, Spirostachys, Suæda, Heliotropium, Pluchea, Populus, Salix,* and *Sesuvium* were among the earliest arrivals on bared areas, but within two years *Isocoma, Parosela, Eriogonum,* and others would appear and these would persist and perhaps be found on ancient beaches. Thus, of the total amplitude of change from a moist saline beach to a dry desert ridge in a few centuries much the greater part takes place with great rapidity and within three or four years after the water has receded from the level of its upper surface.

The total census of the several observational areas from 1907 to 1913 inclusive comprised 61 species, as follows:

Amarantus palmeri.
Aster spinosus.
Aster exilis var. australis.
Astragalus limatus.
Atriplex canescens.
Atriplex fasciculata.
Atriplex hymenelytra.
Atriplex lentiformis.
Atriplex linearis.
Atriplex polycarpa.
Baccharis glutinosa.
Bouteloa arenosa.
Chamæsyce polycarpa hirtella.
Chenopodium murale.
Coldenia plicata.
Conyza coulteri.
Cryptanthe barbigera.
Cucurbita palmata.
Cyperus speciosus.
Eclipta alba.
Eleocharis sp.
Encelia eriocephala.
Encelia frutescens.
Eriogonum deserticola.
Eriogonum plumatella.
Eriogonum thomassii.
Franseria dumosa.
Heliotropium curassavicum.
Hilaria rigida.
Hymenochloa salsola.
Isocoma veneta var. acradenia.
Juncus cooperi.
Lepidium lasiocarpum.
Lippia nudiflora.
Leptochloa imbricata.
Oenothera scapoidea aurantiaca.
Oligomeris glaucescens.
Olneya tesota.
Parosela emoryi.
Parosela spinosa.
Phragmites communis.
Pluchea camphorata.
Pluchea sericea.
Polypogon monspeliensis.
Populus macdougallii.
Prosopis glandulosa.
Prosopis pubescens.
Psathyrotes ramossissima.
Rumex berlandieri.
Salix nigra.
Sesuvium sessile.
Scirpus americanus.
Scirpus olneyi.
Scirpus paludosus.
Sonchus asper.
Sonchus oleraceus.
Sphæralcea orcutti.
Spirostachys occidentalis.
Suæda torreyana.
Typha angustifolia.
Wislizenia refracta.

Modifications of Plants under the Specialized Conditions Presented by Emersed Strands, by D. T. MacDougal.

The disturbances in the Salton Sink following the making and the desiccation of the lake were of course followed by the exposure of many species to unusual intensities of substances, the action of which would have the direct effect of coagulating or hydrating the colloidal substances of the plant body. But little attention could be given to exact measurement or estimation of the effect, but noticeable deviation in leaf and stem characters were observed in 3 of the 61 species which occurred on the strands. These were *Aster exilis, Prosopis glandulosa,* and *Atriplex canescens.* The thickish stems of the modified asters were strikingly suggestive of the hydration effects of alkalies which may be taken to underlie the induction of succulency in the higher plants. In addition to these modifications, species of salt-bush (*Atriplex saltonensis*) and of spurge (*Chamæsyce saltonensis*)

hitherto unknown were found below the level of high-water mark and described by Mr. Parish. It is not easy to point out their origin, but their occurrence within the limits of the Sink only suggests that the conditions prevalent in this restricted area may have had some connection with the matter.

It has been pointed out by Mr. Parish that within the limits of the Sink there also occur *Astragalus limatus*, *A. aridus*, *Cryptanthe costata*, *Calandrina ambigua*, and *Sphæralcea orcuttii*, which are endemic and do not extend beyond the high-beach level, with the exception of *Calandrina*, which has evidently spread over toward the Colorado River. Seven species in all have originated within the Sink and their habitats still lie mainly within its area. Others may have had their origin here and have been disseminated beyond the basin.

VARIOUS INVESTIGATIONS.

Analysis of the Effect of Climatic Complexes, by D. T. MacDougal and Collaborators.

After trials of a large number of species, less than a score have been selected which will live in the climates presented by the mountain plantations in Arizona, in the desert at Tucson, and near the sea-shore at Carmel, California. The experimentation includes attention to two principal features. First, the morphogenesis of the plants under the influence of the differing environic conditions presented is followed, from which it is seen that not only does the character of the seasonal or life cycle vary under different conditions, and the vegetative parts of the plant show distinctive features under the three sets of conditions, but some of these effects are carried over from one generation to another. The reactions of any given species at the Coastal Laboratory at Carmel will therefore vary according to the previous experiences of the individuals or their ancestors. The correlation of these differences with the factors in the climate presents a much more difficult task. It is possible to measure the evaporative capacity of the air as an expression of the combined or resultant action of the wind, relative humidity, insolation, and temperature. Methods are being developed for estimating the insolation effect alone, and the integration of the temperature exposure is one of the most pressing necessities of modern plant physiology.

Averages of maxima, minima, or statements of the range between winter and summer, have only a remote empirical relation to plant activity, which may be exactly conceived only in terms of velocity of chemical reactions and physical change, upon which all vegetative processes depend. Nothing yet brought out is superior in usefulness to the empirical method of integrating the thermographic record proposed by the author in 1901, but this matter has been taken up anew with some faint hope of placing it upon a rational basis.

Alterations Induced by Ovarial Treatments of Plants, by D. T. MacDougal.

The extension of the work upon this subject has been wholly taken up with the cultivation of the second and third generations of the variants or mutants which were secured by the original treatments. In addition to the new forms which have resulted from this method, an additional derivative of a *Scrophularia* has now been secured. The species is a native of the region in which the montane plantation is situated and forms one of the suite of species under experimentation in the various climatic complexes. Some of the seeds, matured in an ovary into which potassium iodide had been injected, produced plants in which the purplish color of the flower of the parental stock was replaced by a cream white, with other morphological and physiological departures. This material is now being carried into the succeeding generation.

It has remained for Col. R. H. Firth, of the Royal Army Medical Corps of Great Britain, to duplicate these results in obtaining atypic forms by ovarial treatments of plants (Firth, R. H., Jour. Royal Med. Corps, 16, pp. 497–514, 1911). Colonel Firth cultivated a number of species of Onagraceæ in soils to which various substances had been added and in this way saw new forms appear. Then injections into the ovaries of *Oenothera odorata* (*Raimannia odorata*), *Epilobium roseum*, and other species resulted in atypic derivatives. Not much success was attained in the cultures of the derived forms at Simla, East India, where the work was performed. Dr. Firth intimates that the induction of forms by ovarial treatment is most easily secured in plants subjected to unusual conditions of cultivation or nourishment, which would support the suggestion mentioned above to the effect that there is no direct relation between the nature of the inciting agent and of the mutations induced. It is of interest to note that Dr. Firth induced mutation in *Raimannia odorata* (*Oenothera odorata*), in which the discovery of the method was originally made by Dr. MacDougal in 1905.

Miss Elizabeth Schiemann, in testing the excitation action of various substances upon the common black mold (*Aspergillus niger*), used potassium dichromate, copper carbonate, zinc sulphate, magnesium oxide, and potassium chlorate, which were simply added to the culture solution of the mold. Two atypic forms of mold were seen to originate in the cultures to which potassium dichromate had been added—one with brownish conidia was named *A. fuscus* and was carried through 40 generations without change; a second, to be known as *A. cinnamonea*, was characterized by conidia colorless at first, which gradually change to sandy, then to cinnamon in color. This form was followed through 34 generations. Other forms, known as *A. niger altipes* and *A. proteus*, appeared in cultures kept at unusually high temperatures.

Evolution of the Chrysomelid Beetles, by W. L. Tower.

A series of experiments has been under way at Tucson, almost from the beginning of the work, consisting of the intercrossings of two or more species without the removal of any of the progeny from the population, with the result that there were produced in a few generations, as previously reported, stable stem-stocks which were the product of the synthesis of all of the characteristics derived from the different parents. Several such stocks are now at Tucson, some of which, under the conditions under which they arose, have remained absolutely constant, and, moreover, on being removed to Chicago and tested under different conditions, they have thus far shown no tendency to break up or to give as extracted forms any of the original parental types or characteristics.

In plate 3, figures 4, 5, and 6, are shown stable stem-forms that have been thus created. That shown in figure 4 is the product of a synthetic union of *L. decemlineata* Say, *L. multitœniata* Stal, and *L. oblongata* n. sp. Some of the stocks, when given proper treatment, especially by changed environic factors, so that the conditions of existence are optimum, can be made to break up, and those which are thus made to break up do so in a manner that is precisely like that which de Vries found in *Oenothera lamarckiana.*

One of our most interesting series is that represented in figure 4, produced by the union of *L. decemlineata* Say and *L. oblongata* n. sp., in which there have appeared thus far about 15 distinct types, some

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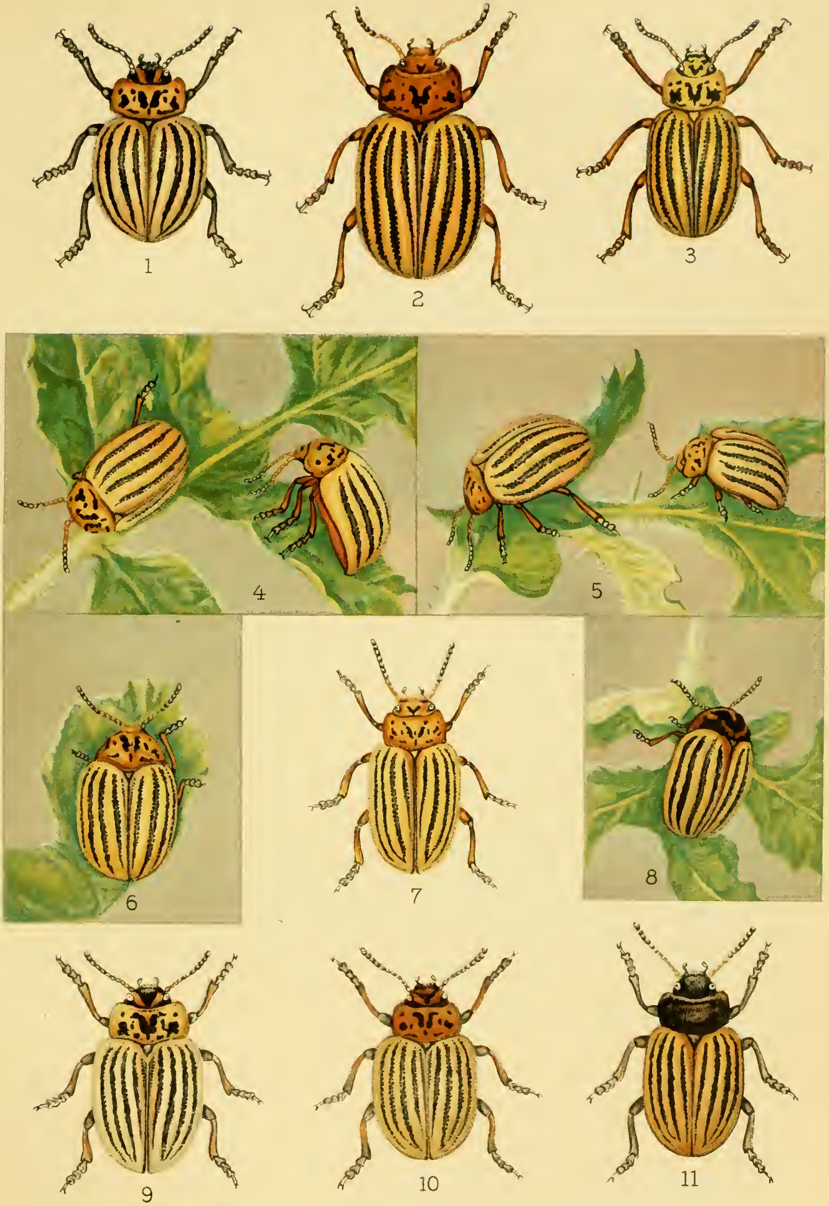
Description of Plate 3.

1. *L. multitœniata* Stal. A normal average form.
2. *L. decemlineata* Say. Normal stock from Chicago.
3. *L. oblongata* n. sp.
4. A mutating stem stock C. H. 15.7, made up of the synthesis of the first two parent species *L. multitœniata* and *L. decemlineata.*
5. Another stable stem stock which arose as the product of the synthesis of all three types.
6. A mutating stem stock of a different origin, composed of *L. decemlineata* and *L. multitœniata.*
7. An elongate mutant that appears in the line A, that breeds true on first appearance. It resembles *L. oblongata* in shape, but in no other respect, and the form exhibited is apparently a new character that arose as the result of this operation.
8. Another mutant that arose from the same series of experiments, showing in pronotal color conditions that come in with the *L. multitœniata* stock, but which have not been present in that stock for many generations.
9. Another mutant from the same stock, also breeding true, showing new combinations from both stocks and the loss of color on the elytron, giving the appearance of a semi-albinic type.
10. Another type of mutant appearing from the same series of experiments, also breeding true.
11. A mutant exhibiting the characters of *L. melanothorax* on the head and pronotum, which could only have come in the line through the *L. multitœniata* parents. The *L. multitœniata* used in this experiment, however, was a pure strain in which *L. melanothorax* was not known to exist. The reappearance of the *L. melanothorax* character, however, in this mutating strain shows either that the *L. melanothorax* character is carried in some condition for a long period of time, or else that there has been produced in this mutation a resynthesis of the character which is *L. melanothorax* in all respects.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of which have been proven repeatedly to breed true on first appearance. Thus in plate 3, figures 6, 7, 8, 9, and 10, there are shown certain of these new mutant forms which have appeared. Each of these forms is, to a considerable extent, simply the combination product of factors which were present in the original parental stocks, but in almost all instances placed in new arrangements. The stem-form, however, does not change and may or may not throw any or all of these types, depending largely upon the conditions of the medium. Thus, for example, a stem-stock which threw these types abundantly during the latter part of the season of 1912 at Tucson does not, under ordinary conditions of the breeding-quarters at Chicago, throw them at all thus far during the breeding-season of 1913, although all are inbreeding and there is no selection, so that there is produced an opportunity to bring about combinations; and if these mutants are the product of Mendelian operations no such effect has appeared. The total result of this type of operation shows most conclusively that this is a true method of producing mutating periods in organisms. In all of the series it is apparently thus far always due to, first, the production of a complex product by hybrid synthesis, and this must be followed later by the incidence of some external factors which then act to break up the synthetic strain, to give, during a period of variable duration, the behavior which de Vries discovered and described as "mutation." This gives a distinctly different conception of what mutation is and its role in the evolution of organisms; and in figure 1, of the plate, is shown in diagrammatic fashion the difference between de Vries's hypothetical mutation hypothesis and the experimental production of the mutation behavior in these Tucson experiments.

In the case of de Vries's hypothesis there is assumed to exist at the start a species, or at least an elementary species, which was breeding true, and that this began to elaborate within its germ-plasm pangenes which were the bearers of new characters. These, after a sufficient period of time, became so numerous in the germ-plasm that the organisms could no longer keep their action suppressed, with the result that with a sudden jump they appear in the mutant form, and that this mutating behavior appears through a series of generations. De Vries's supposition that this behavior was probably ultimately the product of external conditions seems thus far not to have been proven in any of the experimental work, because when external conditions are brought to bear upon a normal homozygous stock they have thus far produced only a single response that is permanent in character, but which was not repeated in subsequent generations. At Tucson two or more stem-stocks are brought together and allowed to interbreed freely, and these eventually produce a stable form through a series of synthetic operations. These stable stem-forms are the

known product of a complex ancestry, exhibit no more range of variability than do either of the parental types, and are found to continue undisturbed through many generations, or if disturbing factors are brought to bear upon a portion of the stock, that portion of the line only exhibits the type of the behavior which de Vries has characterized as "mutation."

These experiments thus show in concrete fashion how a type of behavior that may be immensely important in the production of new varieties and elementary species may be produced. It is a known fact in human history, and it is equally certain in other organisms, that there have been repeated, almost constant, intermingling of different types, and this intermingling of different types may well be the basis of stem-forms which give here and there those sporadic types which are called "sports." It likewise gives a naturalistic aspect to the process which de Vries described and makes it at once open not only to experimental investigation, but quite possibly of some value in operations of economic importance.

The modifications of the antennæ which are of generic or subordinal value in *Leptinotarsa signaticollis,* produced as the result of experimental desert conditions, continue to show their permanency, and in the cultures at Chicago have gone even further than indicated in last year's report. It is desired to attempt to reproduce this sort of structure in the experiments at Tucson, but thus far it has not been possible to get *L. signaticollis* to become acclimated to the Tucson conditions sufficiently to begin the operations necessary for the production of this character.

The many types of cultures now at Tucson, especially those of hybrid composition, all indicate positively that materials of heterozygous composition stand a far better chance of survival and of becoming established in a new, rather adverse habitat, and are distinctly stronger and better able to withstand the conditions of the environmental complex at Tucson than any one of the parental types. This is especially well shown in a culture introduced at Tucson in the first hybrid generation as F_1 heterozygotes from a cross of *L. signaticollis* × *L. diversa.* Neither of the parent species breeds with any considerable success thus far at Tucson. The hybrid culture breeds with success, is able to pass the winter as heterozygotes and also as extracted individuals of both parental types, and this is especially interesting in view of the fact that the winter of 1912–13 at Tucson and the dry fore-summer of 1913 have been the most severe in the history of these experiments, thus indicating that in heterozygous and F_2 extractive material there is increased possibility for change and rearrangement, and for the production of adjustments of one kind or another between the organism and its environment, such that the organism may come to persist in the new habitat.

In the report for 1912 mention was made of transplanting cultures of *L. decemlineata* Say from Chicago to Tucson, which had changed in eight generations, so that in that time it was unable to meet the conditions of ancestral habitat at Chicago and was eliminated by the winter when returned to Chicago. It has been found that a second culture of *L. decemlineata*, a pure normal stock which has been in Tucson but four generations, was also entirely eliminated during the winter of 1912–13 at Chicago, thus making it clear that a change in the organism takes place in much less time than that reported in the previous year. At the same time a test was made on the culture whose activities were reproduced in 1912, and it showed no change in its capacities, being entirely eliminated at Chicago. Both of these lines were tested to some extent during October 1912, and it was found that under uniform conditions of desiccation with a temperature of 15° C., the materials from Tucson did not lose water nearly as readily as material direct from Chicago, and the weighings made of materials during October and early November, which were dug up from normal hibernation, showed that on the basis of net dry weight the material from Tucson was not losing water with the rapidity that the native material did. This means that the loss of water in the material transplanted from Tucson to Chicago is not sufficiently rapid to enable them to resist the low temperatures of a Chicago winter. The lowest temperature which these beetles encountered in 1913 in their hibernation was −3° C.

The general oversight of the experiments at Tucson during 1913 has been in the care of Mr. G. J. Sinclair, who takes the place of Mr. Breitenbecher, who had charge of the work for the three previous years. Through the year there has been a continued effort to perfect a spherical form of atmometer, with the result that we have now devised a form of standard size, 50 mm. in diameter, with a glazed base both inside and out, and having little or no soluble material in its composition. These were tested out during the early part of 1913, and given a more thorough test during the summer at Chicago and Tucson. Of these, two types have been devised—a white type for permanent use and a black for use in the attempt to measure the effect of the sun's insolation.

Treelessness in Prairie Regions, by W. A. Cannon.

Observations on the character, penetration, and variation of roots, and on their relation to the soil environment, particularly as regards water-supply, indicate that in regions of relatively little rain the roots of mesophytic trees usually attain the level of perennially moist soil, that is, soil which is moistened by upward movement from the water-table. This hypothesis assumes that in such regions the

uppermost soil-levels, which are wetted by rains only, do not provide water in suitable amount to support forests. It is in the uppermost soils that most of the roots of mesophytic trees are confined. The root-soil-moisture relation of mesophytic trees is now well established for the semiarid Southwest. Here, having given suitable soils, such resistant species as the mesquite may assume the tree habit if the water-table lies within 40 feet of the surface, and, under such favoring soil-moisture conditions, fairly dense forests are formed. Very similar conditions appear to obtain in the less arid middle West, as well as in other portions of the United States. In Kansas and Nebraska, for example, the depth to water where mesophytic forests are to be found is less than 40 feet. This is along the flood-plains of streams. On the adjacent higher lands the water-table lies at from 60 to several hundred feet, and although the soils may be favorable, forests are wanting. In other regions, as the Coastal Plain of Texas, the higher lands are occupied by xerophytic species of trees and there may not be an intimate relation between the roots of such species and the water-table.

Root Variation in Desert Plants, by W. A. Cannon.

Field studies and experimental work on the variation of the roots of perennials have been carried on for several years with the following as the leading results:

Root-systems of desert perennials may be roughly classed as being either generalized or specialized. The former type, of which the roots of *Franseria dumosa* are given as an example, is capable of greater variation than those of the latter. When grown in shallow soils the roots of *Franseria* are necessarily shallowly placed, and, in this regard resemble those of the cacti. When grown in deep soil, on the other hand, the roots of this species penetrate deeply and do not radiate widely, and thus resemble the deeply penetrating roots of *Zizyphus*.

The cacti and a few other plants have highly specialized roots which lie near the surface of the ground. Such root-systems are differentiated into anchoring roots and widely reaching absorbing roots. When the soil is coarse, as in sand, the absorbing roots either fail to develop or they develop only to a small extent, and the entire system is composed of the anchoring roots. A similar result is derived from an especially favorable water-supply. Thus variation in the cactus type, a highly specialized root-system, is toward less differentiation, that is, toward the generalized root-type, as in *Franseria*.

The garden cultures were confined to several species of native cacti which were given a good supply of water for 24 months and were grown in deep soil, a part of which was sand and a part garden soil.

Two cylindro-opuntias, *Opuntia arbuscula* and *O. neoarbuscula*, of nearly similar subaerial habit, were found to possess in the former fibrous roots and in the latter fleshy roots, under natural conditions. The two species were treated in a similar manner and both had unaccustomed depth of soil and supply of water. The development of both species, however, was not changed, as regards the qualities named.

Opuntia spinosior, *O. vivipara*, and *O. discata* were grown under relatively favorable conditions as to soil-depth and water-supply, and certain specimens were placed where their roots projected in sand. The most striking result was a nearly or total suppression of the absorbing system of the roots in certain cases, by which the modified systems closely resembled the generalized type. An abundant supply of water thus operates to lessen the differentiation of the roots and also to bring about a somewhat deeper placing of the root-system.

For the purpose of bringing about the deepest possible root penetration of normally shallowly rooted species, mainly the cacti, several plants were caused to grow in glass or metal tubes of various sizes.

Jatropa cardiophylla, which in nature has fleshy roots within 5 cm. of the surface, was induced to send roots to a depth of 43 cm.

Fouquieria splendens has a root-system which, in a measure, is intermediate between that of *Franseria* and that of the cacti. The roots usually penetrate less than 37.5 cm., but in tubes transplanted specimens were seen to send roots as deeply as 1.1 meters. Seedlings of the species, 7 months old, formed a main root 47 cm. long.

Opuntia arbuscula, whose anchoring roots usually attain a depth of less than 30 cm. and whose absorbing roots lie as near the surface as 1.5 cm., formed roots 1.12 meters in length in glass tubes. The roots of *O. versicolor*, which also are usually shallowly placed, formed a main root 78 cm. long.

The Root-Characters of Trees Grown in the Coastal Climate of California, by W. A. Cannon.

Studies were made of the root-systems of several native trees of the coastal region and adjacent valleys. The results indicate that the species have each a characteristic type of root development and, further, that each kind of root-system has especial adjustment to the conditions of soil-moisture. The roots may be very extensive laterally, and especially they may penetrate relatively deeply, as in the case of *Quercus lobata*, or, on the other hand, as in *Quercus agrifolia*, they may lie for the most part close to the surface of the ground and thus be in position to advantage directly from the rains. In the last species the more deeply penetrating portion of the root-system is relatively unimportant and probably does not usually

attain to the zone of soil which is moistened by capillarity from the water-table. This type of root-system, also that which includes superficial roots as a prominent feature, is probably to be considered characteristic of trees growing in regions where the water-table is deep and the rainfall relatively small. The open character of the forests in the California valleys, by which the individuals are usually widely spaced, is directly related to the far-reaching superficial roots. This condition is comparable to the relation between root character and species distribution to be seen in many desert perennials.

The Transpiration Behavior of Rain-forest Plants, by Forrest Shreve.

The elaboration for publication of the transpiration data secured in the tropical montane rain-forest at Cinchona, Jamaica, has yielded conclusions regarding the influence of high humidities on transpiration, the relative amounts of stomatal and cuticular transpiration in rain-forest plants, and the influence of stomatal overture on transpiration, and has made possible a direct comparison of rain-forest and desert transpiration activities, through the use of the method of securing relative transpiration data.

Although high humidities (90 to 95 per cent) have been found to reduce the absolute rate of transpiration below its amount at relatively low humidities (55 to 71 per cent), as is to be expected, the rate of relative transpiration continues to be of the same general order of magnitude at all humidities which are well above the minimal point for rain-forest plants. This is equivalent to saying that high humidities cause no physiological response affecting transpiration, but reduce its amount only through their reduction of the evaporating power of the atmosphere.

In plants with hypostomatal leaves the simultaneous measurement of transpiration in individuals with leaves coated above, leaves coated below, and leaves not coated has confirmed the early work of Comes to the effect that either surface transpiring alone does so more actively than when transpiring with the other surface. Taking this increase into account, calculations have been made from series of readings such as to give values for the true stomatal transpiration and for that of the cuticular surface of both the top and bottom of the leaf. The true stomatal transpiration is thus found to be from 42 to 48 per cent of the total water-loss of the leaf. The close relation of transpirational behavior to evaporation is thus shown to have its basis in the fact that rather more than half of the water-loss of the plant goes on through the epidermal surfaces, through which no marked physiological control of water-loss is possible under ordinary conditions of humidity and water-supply.

The amplitude of stomatal movement in rain-forest plants under shade conditions has been found to be relatively small, the ratio of

the minimum average diameter to the maximum being as 1 to 1.5 in ferns and as 1 to 13.3 in flowering plants. The weakness of the movements, together with the high cuticular water-loss, serves to give the stomata a very negligible role as regulators of transpiration-rate, particularly during the daylight hours. Indeed, a few instances have been recorded in which a fall in transpiration-rate, during a 2-hour interval, was accompanied by an increase in stomatal area. No direct evidence has been secured to show that transpiration-rate itself controls stomatal movement.

The securing of relative transpiration data has made possible a comparison of the transpiration behavior and the transpirational water-losses of different individuals of the same species, rain-forest plants of different habitats, and also of rain-forest and desert plants. Individuals of the same species exhibit, in general, the same daily behavior, but the amounts of their water-loss per unit area are often unlike, and are so without discoverable differences in the gross anatomy or environmental conditions of the individuals. This circumstance has made it necessary, for some purposes, to calibrate plants by preliminary measurements of their transpiration, and to compare the water-losses of different species by averaging the results from several individuals. The different species, characteristic respectively of the very moist ravines, of the rather moist slopes, and of the wind-swept and relatively dry ridges of the rain-forest, when investigated under the same conditions, showed transpiration amounts in the proportion respectively of 3.5, 1.6, and 1. The evaporation conditions of these habitats differ, as measured during several months, by amounts which are closely equal to a reversal of the above proportions. This is to say, the actual amounts of water-loss in the plants, when growing in their natural habitats, is approximately the same per unit area.

A comparison has been instituted between the relative transpiration data for the rain-forest plants and those secured at Tucson, by Livingston for several desert ephemerals and for *Parkinsonia* in different vegetative conditions by Mrs. Edith B. Shreve. The most nearly xerophytic of the rain-forest plants exhibit about the same maximum relative transpiration-rates as do the most hygrophytic of the desert herbaceous species. The relative rates for herbaceous plants of the rain-forest, as determined in the shade, are about half of the rates for the desert ephemerals, as determined in the sun, and there is some evidence that this difference is due to the different light conditions in which the two sets of experiments were performed. The rates for *Parkinsonia*, determined in the sun, are of about the same general order of magnitude as the shade rates for the Jamaican herbaceous species. A general review of the data under comparison indicates that, in spite of minor differences, there is a greater uni-

formity among the relative transpiration maxima for the rain-forest and for the desert than might be expected. When such a uniformity is considered in the light of the fact that the evaporation is very many times greater in the Arizona desert than in the Jamaican rain-forest, it forces the conclusion that the transpiration-rates in the plants of the two regions must be roughly proportional to the evaporation-rates, else the relative transpiration-rates would not remain so nearly equal. In short, it is the desert plants in which the rate of transpiration is high and the rain-forest plants in which it is low, which is quite the reverse of the commonly accepted view.

Altitudinal Gradients of Growth-rate, by Forrest Shreve.

Field-work on the relation of altitudinal differences of climate to the growth-rate of the yellow pine has been continued in the Santa Catalina Mountains and has also been prosecuted in the vicinity of the San Francisco Peaks in northern Arizona. In the latter region the pine occurs through a vertical range of 4,000 feet, closely corresponding to its distribution in the Santa Catalina Mountains, and extended stands of it may there be found on deeper soils than those of the abrupt slopes of the Santa Catalinas.

The work as carried out has had in view the securing of altitudinal gradients of growth-rate and also the determining of the influence upon the rate of growth which is exerted by soil character, density of stand, age of tree, and form of crown. It has been found necessary to select areas for study on unlike soils at the same altitude, and to use trees of all ages and of all forms of crown, in stands of differing density, in order that these factors may not mask the effect of the climatic diversity at the different altitudes. The growth data secured in the immediate vicinity of Flagstaff, Arizona, afford an opportunity for comparison of the annual fluctuations of growth for the past 24 years with the climatic record at Flagstaff for that period. Particular importance attaches to the weight of other factors than rainfall and to the determination of the particular months of the year in which occurs the rain of greatest apparent importance in determining the succeeding growth.

Material for the determination of growth-rate has been secured by the use of a Swedish increment-borer, but the large number of measurements necessary in order to bring together all the data bearing on the above problems makes it impossible to state as yet the final conclusions.

Winter Temperature Phenomena in the Santa Catalina Mountains, by Forrest Shreve.

Instrumental readings have been continued on the Santa Catalina Mountains, in connection with other work, with a view to increasing our none too perfect knowledge of the rainfall and temperature

gradients. Rainfall data for the summer season have been secured at seven stations, at vertical intervals of 1,000 feet, for the third year, and they are found to form a far more satisfactory basis for determining the relation of rainfall and altitude than do data from the scattered Arizona stations of the Weather Service. The winter-temperature data for the same stations are confined, perforce, to the absolute minimum for the interval between the last visit of autumn and the first of spring. These data have, for a second time, exhibited a lower minimum at 6,000 feet elevation, in the open chaparral zone, than at 7,000 feet in a pure stand of yellow pine, or at 7,700 feet in the spruce and fir forest surrounding the montane garden. The difference of minimum between 6,000 feet and 7,700 feet is 6° F. Such a reversal of the temperature gradient is not to be related to cold-air drainage, for the stations at 6,000 and 7,000 feet are on ridges, while that at 7,900 feet is in a deep canyon which receives the cold-air flow from the main ridge of the range. The explanation of the phenomenon is probably to be sought in the greater nocturnal radiation of the soil in the unforested altitudes as compared with the heavily timbered elevations, and suitable experimental tests of this possibility will be sought during the coming winter.

The Water-relations of Plants, by B. E. Livingston.

The systematic study of the fundamental water-relations of plants, in charge of Professor B. E. Livingston, has continued through the year, as have also Professor Livingston's climatological studies in relation to plant distribution in the United States. As has been previously announced, these climatological studies are planned as a part of a collaboration on environmental conditions and phyto-geography between Professor Livingston and Dr. Shreve. The manuscript and charts of this work are now nearing completion, having been greatly delayed by unforeseen complications in the climatological calculations, etc., the work thus consuming more time than was expected.

The investigation of the water-relations has definitely reached the stage where quantitative knowledge of some of the subterranean environmental conditions is necessary, and the past two years have been largely devoted to the elaboration of physical methods which may be of value in this connection. The growth of plants depends, as far as water-relations are concerned, upon the amount of water available within the plant body. This, in turn, is a function of two variables: (1) the possible rate of water-supply to the water-consuming tissues and (2) the rate of water consumption, mainly loss by transpiration.

The first part of these investigations involved studies of transpiration and the conditions controlling it. In this connection a fairly satisfactory set of quantitative methods has been devised

(including the porous cup atmometer, now in general use, the radio-atmometer, and the standardized cobalt-chloride paper tests of foliar transpiring power), and the main conditions affecting transpiration composing the aerial environment complex in regard to water-relations are now fairly susceptible of measurement.

The second part of these studies involves much more difficult problems. In the first place, comparatively little is known about the subterranean surroundings of plants, this subject never having received nearly as much attention as have the aerial surroundings. In the second place, researches upon soil-water conditions involve a much more difficult set of physical problems than do those of the aerial-water environment. It has thus been necessary to attempt the elaboration of new methods for measuring the water conditions of the soil as these affect plants. While considerable progress has been made in this direction, it is not yet possible to announce satisfactory methods for determining the conditions controlling the possible rate of water entrance from soil to roots. These are the main environmental conditions that remain to be brought under quantitative methods, and to them much attention is now being given.

During the summer of 1912 Professor Livingston was assisted at Tucson by Mr. E. M. Harvey, of the University of Chicago, who carried out a series of measurements of the power of the soil to extract water from a water-supplying surface, it being assumed that this power is directly proportional to the resistance offered to water absorption by roots. This procedure promises to be of value, but possesses objectionable features, and more work will be necessary before it can be stated within what limits and under what conditions it may be available for the main problem in hand.

Dr. Lon A. Hawkins, of the U. S. Department of Agriculture, assisted Professor Livingston in the Laboratory of Plant Physiology of the Johns Hopkins University during the period from October 1, 1912, to June 1, 1913, and carried out a somewhat elaborate series of determinations of the moisture relations obtaining between soils *en masse* and samples of the same or different soils separated from the main soil by a porous clay wall. The results obtained remain mainly to be subjected to calculation, but, while this will surely be useful in some ways, it promises, as a method, little more than a new and convenient means of soil sampling for water-content determinations.

The ability of soils to supply water to a standardized osmotic cell or osmometer (considered preliminarily in Publication No. 50) has also received considerable attention. Mr. H. E. Pulling, of the University of Wisconsin, assisted Professor Livingston in this work during the summer of 1913. After many failures it now appears at least that a suitable osmotic membrane and mounting for this study have been attained. This matter will be reported at a later date.

Aside from the difficult problem of measuring and integrating the effective soil-moisture conditions, it is frequently desirable, in experimentation, to maintain these conditions constant for a longer or shorter period of time, and these investigations have furnished the auto-irrigator for this purpose. During the winter of 1912–13, Professor Livingston and Dr. Hawkins operated a number of these instruments on plant cultures in the green-houses of the Johns Hopkins Laboratory of Plant Physiology, and determined the variations in soil-moisture content which may be expected with this instrument. The range of these variations proved to be exceedingly narrow. These results will be embodied in a journal article.

Mr. J. W. Shive, of Johns Hopkins University, assisted Professor Livingston in Baltimore during the academic year 1912–13, carrying out certain other experimentation upon the action of the auto-irrigator, and also assisted in various ways at Tucson during the summer of 1913. The relation of the soil-moisture residue at the time of wilting to the evaporating power of the air which prevails during the wilting period has received further attention at the hands of Mr. Shive, this work being carried on at the Desert Laboratory. This line of study, begun by Dr. W. H. Brown, now of the University of the Philippines (assistant in this work during the summer of 1910), and continued by Professor J. S. Caldwell, now of the Alabama Polytechnic Institute (assistant during the summer of 1911), has proved to be of considerable importance in scientific agriculture as well as in ecology and plant physiology.

The quantitative determination of the capacity of plant foliage to resist transpirational water-loss, by means of the method of standardized cobalt-chloride paper, which was devised in 1908 by Professor Livingston, in the laboratories of the Pflanzenphysiologisches Institut at Munich, received attention from Mr. A. L. Bakke, of the Iowa State College. Mr. Bakke spent the summer of 1913 in this work, as a visitor at the Desert Laboratory. His results corroborate, in general, those already published by Professor Livingston and carry knowledge of this matter markedly forward. The degree of water-withholding capacity exhibited by leaves (their degree of xerophytism, in the current ecological sense) can not be accurately predicted from morphological examination of the leaf structures. Mr. Bakke's work will appear in a journal article.

Autonomic Movements of Stems of Opuntia, by Edith B. Shreve.

Observational and experimental work has been continued on the movements of branches of *Opuntia versicolor*, with a view to determining the exact nature and the cause of the phenomenon. Joints from 1 to 5 years old on both large and small plants exhibit vertical movements which vary in amount from 10° to 170° and horizontal

movements usually less than 10°. These motions are clearly related to the soil-moisture conditions. The downward motion takes place slowly, the lowest position being reached in from 4 to 6 weeks after the last rainfall, while the upward motion begins within a few hours after the first significant rain and is completed within a few days. A week or so of drought will start the downward motion, which may be in turn interrupted by a rain or by artificial irrigation, but no downward motion begins so long as the water-content of the soil remains high. All evidence thus far is that the motion is a purely mechanical one caused by the varying balance between the forces of gravity, turgidity, and elasticity of the tissues.

In addition to this seasonal motion, small plants which have been kept in the green-house for a few months in moist soil show an upward motion of from 2° to 20° during daylight and usually a downward motion during the night. In two cases hot-house-grown plants have shown a slow rise during the daylight hours of several days until a vertical position was reached, and then a sudden drop through 180° to the opposite side, and then again a slower rise to the vertical, the whole story being repeated several times. By the use of mirrors and shades it has been shown nearly conclusively that this upward motion takes place only when the upper half of the stem is exposed to direct sunshine; a downward motion was induced by shading the top and reflecting sunlight on the lower half. These facts, together with the shape of the curve of bending, seem to indicate that this daily motion is due to a slight shrinking of the tissues on the illuminated side, caused by the faster evaporation on that side, and a consequent unequal set of stresses which tend to erect the stem. However, the rate and even the existence of this motion are greatly influenced by several other factors, among which the inter-relation of the moisture-content of the plant, air, and soil, the temperature of the air, and the geotropic erection of the growing-point have been shown to be important. The united operation of these factors makes the experimentation difficult to carry on under controlled conditions. Relative transpiration of potted individuals was measured under different conditions of water-content of both plant and soil, a record being kept of the motions of the branches at the various times. The amount of relative transpiration, as determined by comparison with the Livingston atmometer, was found to vary greatly with the water-content of plant and soil, the sun-transpiration of a plant which had been kept well watered for several months being 92 per cent greater than that of the same plant when it had been three months without irrigation. In the first case the relative transpiration was greater for the day than for the night, but was a very appreciable amount for the night, while in the second case the plant actually gained in weight, during the night, the same

amount that it had lost the previous day. When this same plant was given abundant water the stem began to rise within an hour and within two days had reached the position occupied three months earlier, but the relative transpiration was greater for the night than for the day. Dr. Livingston had previously found that the relative transpiration rates for several species of cacti is greater at night than in the day, but he recorded 24 per cent of his plants as behaving "abnormally" and attributed this to pathological conditions. This work seems to show that this 24 per cent was probably made up of plants which were behaving normally but were under a different complex of water relations from the others. The gain in weight at night was large enough to attract attention and experiments are planned to prove whether or not the gain is actually due to the absorption of water-vapor. Not until this has been completed can any connection between transpiration and the movements be established.

The Transpiration of a Desert Tree, by Edith B. Shreve.

The results of the investigation of transpiration in *Parkinsonia microphylla* have been made ready for publication and are now in press. Some of the main conclusions reached are as follows:

Transpiration-rates from trees and potted plants differ so greatly in amount and in hourly changes that conclusions regarding the one can not be drawn from measurements of the other.

Potted plants when grown under several conditions of air humidity showed differences in anatomical structure which ranged from the purely mesophytic type to the extreme xerophytic type, and transpiration measurements of these different forms showed that the maximum relative-transpiration amounts varied with the degree of xerophytism of the structure. Further, the maximum rate varied greatly in any given plant according to its soil-moisture content.

Both potted plants and adult trees exhibit in their daily curve of relative and of actual transpiration a drop which precedes the maximum evaporation-rate for the day by 1 to 4 hours. This drop is followed in the majority of cases in potted plants, and always in trees, by a recovery. Curves constructed from measurements of stomatal openings, water-content of leaves, and leaf-temperatures paralleled the transpiration curve.

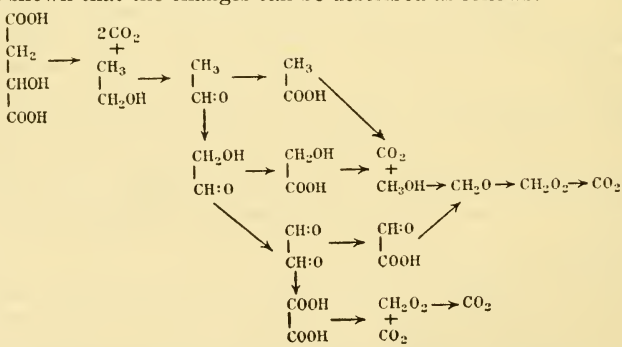
From the evidences of water-content and leaf-temperature determinations the theory is advanced that the drop in transpiration occurs because the tissues have begun to dry out and the water is not there to be given off at the same rate. This is really further evidence of Livingston's theory of "incipient" wilting and Renner's "saturation" deficit. In order to account for the recovery after the drop an adaptation of Dixon's theory of ascent of sap in trees is made by holding that the deficiency of water in the leaves at the time of increasing evaporating power of the air causes the tensile pull on the

water-columns to begin or to become greater and thus to draw water from other parts of the plant until the intake is nearly equal to the outgo. It is also suggested that the closure of the stomata is caused by a slight drying out of the tissues and thus takes place after the transpiration-rate has been cut down.

Since, as is well recognized, the transpiration-absorption ratio is the most vital factor governing the occurrence and distribution of plants in desert regions, the facts appearing from this work are surely connected with the success of *Parkinsonia* as a desert perennial. In addition to its seasonal responses, such as the dropping of leaves and the dying of branches, there is this daily response which begins with a closure of the leaflets and is followed several hours later by a decrease in the transpiration-rate while the evaporating power of the air is still increasing. Dr. Forrest Shreve has found that seedlings of this plant withstand the drought seasons only with difficulty, the percentages of deaths being very high during the first year and becoming less each succeeding year. The mesophytic type of foliage and stems of the young plants makes the water-loss from such plants higher than from older ones, and the low mechanical strength as shown by the anatomical structure would probably mean that they could not withstand the earlier stages of drying without losing their turgor.

The Photolysis of Plant Acids, by H. A. Spoehr.

A careful study of the photolysis of malic acid and of its products has shown that the changes can be described as follows:



Briefly, the organic acids split off carbon dioxide, the dibasic very much more easily than the monobasic; in the presence of atmospheric oxygen, alcohols are readily oxidized to aldehydes, and these in turn to acids. Of special interest is the formation of oxalic acid from acetaldehyde, as this is a possible explanation of the presence of the large amounts of this acid in the succulents. Although free

oxalic acid is very easily decomposed in the light, small amounts daily unite with calcium to form an insoluble and photochemically stable compound within the cell. It was found that on diminution of the total acidity of *Opuntia versicolor* joints and other richly acid cacti the amount of volatile acids increased. The formation of the relatively photochemically stable acetic and formic acids from malic acid would explain this fact. The observation of Kraus that the rate of decrease of acidity in a succulent diminishes under constant light and temperature conditions can also be explained hereby. The formation of formaldehyde from malic, glycollic, and acetic acids in the light substantiates the criticism that no conclusion can be drawn as to the correctness of the Baeyer hypothesis of carbon dioxide assimilation from the finding of formaldehyde in illuminated leaves. There is some evidence that other plant acids also yield this aldehdye. It is now evident that there are substances formed in the photolysis of plant acids from which sugar can be synthesized by the plant. The results from this study are applicable not only to succulents, but to all green leaves, for the processes and products of the aerobic respiration of sugar are the same in both cases. In the succulent there is simply an accumulation of the malic acid at night, due to an insufficient supply of oxygen.

Photolytic Effect of Blue-Violet Rays and Their Variations in Solar Radiation, by H. A. Spoehr.

The biological importance of the blue-violet rays is constantly becoming more evident. A comparison of the results obtained with a Smithsonian Institution pyrheliometer and those obtained with the chemical photometer shows that a knowledge of the total insolation (as obtained with the pyrheliometer) is of limited value for the study of climate from a physiological point of view. It has been found that the intensity of the violet rays shows sudden and unpredictable variations quite independent of the variations in total intensity. Winter values are decidedly less than those of the summer,

Results obtained with the Smithsonian Institution pyrheliometer No. 16, means for months indicated, expressed in standard calories per square centimenter per minute.

Station and month.	$8^h 45^m$ a. m.	$10^h 30^m$ a. m.	$11^h 45^m$ a. m.	1 p. m.	$3^h 30^m$ p.m.
Tucson—Desert Laboratory (2,700 feet).					
1912, June	1.441	.....	1.466	.....	1.410
Mount Lemmon.					
1912, June	1.520	.....	1.661	.....	1.432
Tucson.					
1912, September	1.175	.....	1.302	.....	.990
October	1.011	.....	1.241	.....	.908
November	1.125	.....	1.259	.....	.751
December	.928	.....	1.320	.....	.855
1913, May	1.345	.....	1.429	.....	1.224
June	1.331	1.427	1.435	1.420	1.285

and the afternoon is generally weaker than the morning. Clouds, of course, have a great effect on the violet intensity, while the reflection from cumulus clouds seems to increase the values; the highest intensities were obtained on days on which there was a "tendency" to cloud formation.

Monthly means of per cent of oxalic acid decomposed in the photometer in one hour under uniform conditions.

TUCSON—DESERT LABORATORY (2,700 FEET).

Month.	Morning mean.	Temperature mean.	Cloudless days, mean.	Maximum.	Minimum.	Afternoon mean.
1911.						
December	14.44	19.8	15.76	18.47	6.07	....
1912.						
January	17.15	25.4	17.22	17.76	16.85	....
February	18.58	25.7	18.72	20.38	17.27	....
March	18.50	28.0	20.43	20.84	13.90	....
April	21.96	33.0	21.99	22.30	20.81	....
May	21.16	34.9	21.82	23.43	19.05	....
June	21.63	42.1	21.95	22.70	20.09	18.52
July (no record)	....	....	....	....	....	....
August	19.89	38.2	....	21.85	10.37	16.24
September	22.61	39.7	22.72	23.75	20.63	21.40
October	21.51	29.3	....	22.21	21.02	18.85
November	15.76	24.7	17.09	18.17	10 03	14.76
December	15.71	21.3	16.15	16.92	14.05	13.56
1913.						
January	15.24	20.9	15.10	17.25	12.30	14.10
February	17.66	23.5	17.66	18.05	17.00	....
March	20.81	26.5	21.03	22.18	18.82	20.17
April	22.43	31.6	21.63	23.63	20.39	....
May	23.09	35.6	23.13	23.79	21.96	....
June	22.10	39.8	22.10	22.47	21.31	22.08
MOUNT LEMMON (9,250 FEET).						
1912.						
June	18.28	24.2	20.26	21.23	14.93	....

Acidity, Gaseous Interchange, and Respiration of Cacti, by H. M. Richards.

During the winter of 1912–13 the main work consisted in the analysis of gas samples obtained in Tucson during the previous summer. These samples were taken from closed flasks, in which joints of cacti were exposed for definite periods under a variety of conditions, and were carried to New York in glass containers sealed with dry mercury. From the analyses of these a large mass of data was obtained which has been calculated out and reduced by Miss M. E. Latham, who has also made most of the analyses.

Additional determinations of intramolecular respiration and temperature effects on respiration were also made during the winter, with the usual Pettenkofer apparatus to supplement and confirm previous results.

During the spring an apparatus was devised, somewhat modified from that of Aubert and other workers, for the more accurate deter-

mination of the gaseous interchange. This apparatus consists of a closed flask with mercury seal, to which is attached a graduated manometer and suitable means of drawing off a known amount of gas from the flask. The decrease in pressure resulting from the withdrawal of gas gave the necessary data for calculating, with considerable accuracy, the capacity of the flask containing the experimental material. Previous to the determination of the capacity, however, the gas sample to be analyzed had been drawn off at a much less diminished pressure, usually not more than a negative pressure of 5 or 6 mm. of mercury. For this a special arrangement was provided. This is a not unimportant precaution, for under greatly diminished pressure gases held in the plant tissues are drawn out which would entirely vitiate the result.

Six of these gas-flasks were taken to Tucson in the early part of the summer, so that a considerable number of experiments were carried through in a relatively short time. The gas samples were preserved as before. The object of these experiments was twofold: (1) to fill out certain lacunæ in the work of the previous year and (2) to obtain data from which the actual amount of CO_2 evolved and of O_2 absorbed could be more accurately calculated than by the previous method.

Especial attention was paid to experimenting with plants the acidity of which might be presumed to be falling from a near maximum or rising from an approximate minimum of acidity. Parallel acidity determinations were made in every case. From the analyses of last year's experiments it also appears that the gas interchange of the cacti under exposure to diffuse daylight and bright sunlight is of great interest. Series of experiments were therefore run under these conditions. Analyses of the gas samples taken from all these experiments are being made by Miss Latham. At the lower temperature and equable conditions found at Carmel experiments have been carried on, the results of which will be determined later.

The ratio of the $\frac{CO_2}{O_2}$ interchange appears to be a function of the acidity rather than a matter of the age of the cactus joint and is more nearly unity when the acidity is high. Consequently, as stated in last year's report, the younger joints, in which the highest acidity has been found, behave more like the ordinary plant in this regard than do the older portions; or, in other words, the greatest absorption of oxygen comes in the process of disappearance of the acid and is less marked during the accumulation thereof.

From the results obtained in this work, as well as from the information afforded by the work of Dr. Spoehr, it seems undoubtedly to be the case that much of the evolution of CO_2, at least during the period of diminishing acidity, is not respiration in the restricted sense of the term. This is especially true probably of the CO_2 evo-

lution which takes place in daylight or that which occurs with higher temperatures after the optimum has been reached.

Fruit Development in the Cactaceæ, by D. S. Johnson.

The fruits of the opuntias, or flower-bearing joints as they might be called, exhibit many intermediate types of structure between that of typical fruits and that of ordinary vegetative joints. In external form the ripe fruit may be nearly globular, with mamillæ only slightly evident, or it may be elongated to three or four times its diameter and have, except for the cup in the torus, very nearly the appearance of a vegetative joint. Internally there may be an ovarian cavity of three-fifths the diameter of the fruit, or it may be less than one-fifth this diameter. The cavity may be central in the more globular fruits or close to the apical end in the elongated ones. Over half of these mature fruits contain a number of ripe seeds, which may vary from 1 to 100 to each fruit. Other fully grown fruits contain only shriveled rudiments of ovules. Some of these evidently ceased development at about the time of pollination, while others had attained to one-fourth or half the mature size when degeneration set in. Not all flowers, however, give rise to structures having the form of mature fruits. A certain percentage of the potential fruits drop off soon after flowering. One is inclined to conclude that pollination occurs only in mature fruits, and also that among these fruits seeds are formed only in those cases where fertilization as well as pollination takes place. The latter conclusion is rendered doubtful, however, by the fact noted above, that matured fruits often contain seeds that have degenerated after becoming half grown. Field work is needed to settle both these questions definitely.

In the fruits increase in age is marked not only by increase in size and change in the form of the fruit as a whole, but also by changes in the size and character of the areolæ. The latter are but 1 or 2 mm. across when the subtending leaf falls off. In older fruits they protrude far above the surface and become 5 or 6 mm. in diameter. This growth is due to the development of some dozens of new bristles and of successive ring-like series of new hairs. The other organ rudiments present in the areola apparently remain practically dormant.

The matured fallen fruits have the unique function, for a fruit, of serving as propagules for the development of new plants. The first indication of the origin of a new plantlet from such a fruit is the pushing out of one or several young roots, which form the apical margin of an areola. It is worthy of note that these roots arise above the clump of bristles, beyond the limits of the growing-point of the axillary bud, and not within these, as is always true of the flower rudiments, and apparently of the new shoot rudiments also. These adventitious roots are probably entirely internal in origin. At any rate, vascular supply of the plantlet is connected quite independently

with one of the larger bundles of the old fruit. It has been determined that the origin of a plantlet from a fallen fruit is not dependent in any way on the presence of seeds in this fruit. If ripe seeds are present they are in no way affected by the process of sprouting of the fruit.

Another fact to be explained only by the aid of experimental work in the field is that the axillary buds give rise to *flowers only* so long as they remain attached to the mature plant, while the buds of fallen fruits give rise to *roots and shoots only.*

The Relationships and Distribution of the Cactaceæ, by N. L. Britton and J. N. Rose.

In the early part of the year Dr. Britton and Dr. Rose, with a party of assistants, visited some of the West India Islands, where they made large collections of cacti and of plants in general. Collections were made on St. Thomas, St. Jan, Tortola, Virgin Gorda, Anegada, St. Croix, St. Christopher, Antigua, Porto Rico, Santo Domingo, and Curaçao. Especial attention was given to the drier parts of the islands, on account of the greater number of cacti to be found there. The collection of living cacti brought back is undoubtedly the largest ever made in the West Indies. Not only were new species collected, but also species which were heretofore wanting in our collections, having been known only from meager descriptions. Among the most interesting of these are the *Cactus mamillaris* of Linnæus, found on Curaçao, heretofore unknown in American collections, and an *Epiphyllum* from Antigua, represented only by a drawing at Kew. The collections are being grown in Washington and New York City, a part being used for exchange purposes.

It is fitting to call attention again to the great assistance rendered by volunteer collectors, who have sent in material from all the cactus regions in North America, and to some valuable contributions from South America. Up to the present time more than 100 volunteer contributors have aided in this research.

The manuscript on the subfamilies Pereskioideæ and Opuntioideæ is practically completed, with the exception of many South American species which must await further field studies.

The exploration of the South American deserts is the most important piece of field work to be undertaken, and plans are now being made to begin shortly the study of the Chilean, Peruvian, and Bolivian deserts, to be followed by extensive explorations in Argentina the following year.

During the year two preliminary papers were published by Dr. Britton and Dr. Rose, in which four old genera were restored and two new genera and eleven new species were described. In one of these a reclassification of *Epiphyllum* and its allies was given. By the description of these new species considerable valuable material is made available for exchange purposes.

DEPARTMENT OF ECONOMICS AND SOCIOLOGY.*

HENRY W. FARNAM, CHAIRMAN.

Substantial progress has been made in the Contributions to American Economic History during the past year. In the case of six of the twelve divisions the final reports are approaching completion and we hope to have four of these ready for the press next spring, the other two within a year. This statement applies to the divisions Population and Immigration, in charge of Professor Willcox; Mining, in charge of Mr. Parker; Transportation, in charge of Dr. Meyer; Domestic and Foreign Commerce, in charge of Professor Johnson; Labor Movement, in charge of Professor Commons; Social Legislation, in charge of the chairman. The details of revision and verification will inevitably take considerable time, even in the case of those divisions which are most advanced, but the general character and scope of these reports is now substantially determined, and the writer is able to speak from personal knowledge of the work done under the charge of Professors Commons and Meyer, in consequence of a visit which he made to Madison in the spring of the year in order to look over their material.

In the Division of Manufactures comparatively little work has been done for several years owing to the absence of Dr. Clark in the Hawaiian Islands. He has now, however, given up his government position and will devote himself intensively to work for the Carnegie Institution of Washington during the winter. In the case of three divisions—Money and Banking, under Professor Dewey; Federal and State Finance, under Professor Gardner; and the Negro in Slavery and Freedom, under Mr. Stone—work which was well begun and for which a number of valuable studies have been made has been interrupted either by ill health or misfortune. The Division of Agriculture and Forestry has been delayed by the many demands, some of them of a public nature, made upon the time of President Butterfield, but arrangements have been perfected during the year for the completion of the study of the History of Agricultural Production from 1840 to 1860, under Professor Taylor, of the University of Wisconsin.

The progress made by six of the divisions, as explained above, naturally confronts us with the problem of publication. Some 66 volumes of monographs have been published under this Department since its organization, but the Carnegie Institution of Washington has not incurred any expense in printing them. The Index of State

*Address, Yale University, New Haven, Connecticut. (For previous reports see Year Books Nos. 3–11.)

Documents is the only part of our work for the publication of which the Institution has made itself responsible. It seems to the writer undesirable that this Department should be obliged to appeal to commercial publishers to issue its completed volumes. In the nature of things, works of this kind can not count on a large popular sale and are, therefore, not likely to prove attractive as a purely business proposition. It is, therefore, respectfully urged that provision be made in the publication budget for a sufficiently large sum to provide for the issue of several of the reports during the next year.

The difficulty of bringing to a speedy conclusion twelve different divisions of a large subject without sufficient funds to pay salaries to the authors emphasizes the importance of considering the reorganization, on a permanent basis, of the Department of Economics and Sociology. This is a subject to which the writer has invited the attention of the Trustees in his reports for 1912 and 1911. The need of such a reorganization has been apparent for a long time, and it is appreciated by no one more than by the collaborators themselves, who, in order to be prepared to meet any request that might come from the Trustees, discussed and adopted, in October 1912, the outline of a plan which they believe would be successful if put into operation. Such a reorganization, either on the lines suggested or on other lines, might be carried on independently of the present organization, which was adopted specifically for the Contributions to American Economic History. The foundations for these are so well laid, and so large a part of the final summaries is done, that each of the heads of divisions can complete his own task without making any demands upon a reorganized department, excepting for routine matters of accounting and supervision.

The need of reorganization is emphasized in the present year by the fact that the writer has accepted the appointment to the Roosevelt Professorship in Berlin for the winter of 1914–15. This will involve his absence from the country for a good part of a year, probably from July 1914 until May or June 1915. It will, of course, be impossible for him during that time to give much attention to the work of the Institution, and it would seem better to proceed at once to the reorganization of the Department than to appoint a substitute and adjourn the whole question for a couple of years. Any reorganization inevitably involves an appropriation adequate for the purpose. The writer respectfully urges upon the Trustees the desirability of giving this matter serious consideration. The multiplicity of publications and discussions regarding economic and social questions, while it indicates the public interest in these subjects, also calls attention forcibly to the need of trustworthy information regarding them. A department applying scientific methods intensively to a limited field of the general subject of economics and sociology would, in the

opinion of the writer, perform a function which is not performed at present by any organization and which would harmonize with what he understands to be the general principles on which the work of the Carnegie Institution is organized.

The department as a whole shows an unused balance of about $50,000. Of this apparent balance about $17,000 is in the funds for administration and the Index of State Documents, while $8,825 is in the special fund for the remuneration of the heads of divisions. We thus have available for research about $24,000, and this is very unequally distributed among the various divisions, some of which have almost exhausted their appropriation, while others have a balance of several thousand dollars to their credit. The writer prefers not to ask the Trustees for any additional appropriation as long as it is possible to pay the expenses of the year by transferring money from those divisions which have much to those which have but little. It will be noticed that, speaking broadly, those divisions which have made the most progress on the final report are those which have the smallest balances. It should be realized, however, that a very large piece of work has been undertaken, the magnitude of which has become more apparent with time. While those divisions which have made the most progress may be able to complete their task by drawing upon the balance of some of the other divisions, it should be remembered that this is a case in which one hand is lending to the other, and it may be necessary to obtain additional funds in the future, in order to bring the work of all of the divisions to a conclusion.

Details of the work as reported by the heads of the several divisions are given below.

Division I.—Population and Immigration.

Professor Walter F. Willcox arranged last year to have his work at Cornell University reduced to half its usual amount, and he has devoted the other half of his time to his work on Population and Immigration. He has presented an analysis of the chapters and has written the equivalent of about sixteen of them. He has now obtained a leave of absence from Cornell University for the second half of the year 1913–14, and it is his expectation and hope to have his report ready to print by September 1914.

Division II.—Agriculture and Forestry.

Since the last report, Professor Henry C. Taylor, of the University of Wisconsin, has arranged to have some of his assistants work upon an intensive study of agricultural production from 1840 to 1860, a subject on which he has gathered a large amount of material. Dr. L. C. Gray has already nearly finished a study on agricultural production in the South, as a part of this work, and Mr. J. I. Falconer

is to take up the subject of agricultural production in other parts of the country during the winter. Professor Taylor has prepared some valuable maps in connection with these studies, which have proved to be a source of income to the division.

Professor B. H. Hibbard, who was formerly at Ames, Iowa, but has now accepted a professorship in the University of Wisconsin, has continued his study of federal land policy and expects to complete it soon.

The chairman examined the material of Professor Taylor and Professor Hibbard during his visit to Madison in the spring of the year, and discussed plans with them.

Professor F. W. Blackmar is continuing his study of American agriculture down to 1840, but has nothing finished.

Division III.—Mining.

Mr. E. W. Parker reports that no monographs have been published since September 1, 1912. The manuscript of the chapter on the copper-mining industry has been received from Professor L. C. Graton, though he has, as a result of recent and personal investigations in and around Butte, Montana, withdrawn a portion of the manuscript for revision.

The work still unfinished consists of the chapters on the iron industry, the quarrying industry, chemical minerals, and mining law. These chapters have, however, all been promised for the end of the present calendar year. The chapter on iron mining, by Professor C. K. Leith, is well advanced and some of the manuscript is completed. Dr. Laney has not been able to make the same satisfactory progress on the quarrying industry, as he has undertaken some important work to be completed through the cooperation of the Geological Survey and the Bureau of Mines. He has, however, received much assistance from Mrs. Laney, and will be able to furnish Mr. Parker with sufficiently detailed notes to enable him to prepare his own report by the time the other manuscripts are in hand.

Division IV.—Manufactures.

Dr. Victor S. Clark, who has been engaged for the past few years in census work for the government in the Hawaiian Islands, has resigned his position and returned to the United States.

No monographs have been published or finished in this division since September 1, 1912. The unfinished work is in the same state of progress as a year ago, since Dr. Clark's absence and a pressure of duties in connection with winding up his government work in Hawaii prevented him from giving it his attention. He expects, however, to give all his time to the work after September 1.

Division V.—Transportation.

The manuscript for the first volume of Dr. B. H. Meyer's final report is practically ready for publication, except for checking and re-reading. It covers the period down to about the middle of the century.

The following volumes have been published since the last report:

Railroad Finance: By Frederick A. Cleveland and Fred. Wilbur Powell. New York, pp. xv + 463, 1912. (This is the second volume of a study on railroad finance made under an arrangement with Dr. Cleveland and subsidized in part by the Division of Transportation.)

The Granger Movement: 1870-1880. By Solon J. Buck. No. XIX of the Harvard Historical Studies, XI+384, 1913.

Of the monographs mentioned in earlier reports as having been undertaken, two have been practically completed, namely:

Transportation on the Great Lakes. By G. G. Tunnell.

The Development of Transportation in the Pacific Northwest. By Frederick A. Young.

It is doubtful if the others will be finished, since for various reasons the authors have found their plans interfered with.

Division VI.—Domestic and Foreign Commerce.

No monographs have been published in this division since the first of September 1912.

The volume upon the History of the Coastwise Commerce, by Assistant Professor Thomas Conway, jr., is completed. There is no unfinished work. Dr. T. W. Van Meter, Professor G. G. Huebner, and Mr. D. S. Hanchett, who has been added to the list of Professor Emory R. Johnson's assistants, are working on the final draft of the volume on Domestic and Foreign Commerce. Professor Johnson writes:

These men have been at work this summer and have agreed to continue their assistance until all the chapters of the volume are in my hands. I personally wrote the first quarter of the volume; the other three-fourths of the volume will be written under my supervision by these three assistants, whose work I will edit and rewrite to the extent that may be necessary or advisable. My plan is to submit the volume not later than June first of next year; possibly it can be submitted a little earlier than that.

Division VII.—Money and Banking.

Professor Davis R. Dewey writes as follows:

There is practically little further work tc be done by assistants, the completion of the task being almost entirely dependent upon my own services. I greatly regret that I can not report any very definite constructive progress during the past year. I have continued to work upon the subject and am devoting what time and strength I can during the summer. Unfortunately, during the past year I was incapacitated for several weeks by illness and only recently have gained strength which permits me to do very much additional work.

Division VIII.—Labor Movement.

Professor John R. Commons reports as follows:

During the past two years Mr. Selig Perlman has been continuously engaged on the work of the labor history, and the preparation of material has been narrowed down to the work of five of my former students, namely, John B. Andrews, Helen L. Sumner, H. E. Hoagland, Selig Perlman, and David J. Saposs, who have been working with me, beginning in 1904, on this subject. To each is assigned a certain period designated as follows: Colonial Beginnings (to 1825); Citizenship (1826–1839); Humanitarianism (1840–1857); Nationalization (1858–1877); Upheaval and Reorganization (1876–1897). A concluding period, to be designated as Contemporary Conditions (1898–1913), is to be prepared by me.

By special arrangement these collaborators met with me during July and August 1913, and by daily conference a satisfactory arrangement for uniformity of treatment has been worked out on the basis of a two-volume work of about 400,000 words.

It was hoped that the manuscript could be completed and ready to be copied for the printer by September 1 of this year, but this has been found impossible. The revision of material will require additional time, and the concluding part on Contemporary Conditions since 1898 remains to be written. I have arranged to carry on this work during the coming year in connection with my courses of university lectures and my seminar on labor history.

Within the year Professor Ira B. Cross has completed his study of California Labor History down to 1883, parts of which had already been published in monographs, and Mr. Louis Mayers has finished his thesis on the Greenback-Labor Party of 1876 to 1884.

Division IX.—Industrial Organization.

Professor J. W. Jenks writes, as he has done for the past four years, that his work is suspended until two or three of the other departments have handed in their reports, in order that he may utilize their material and thus avoid duplication of work and expense.

Division X.—Social Legislation.

No monographs have been published or received since the last report and the writer does not count on getting many more special studies of this kind, since the few that have been undertaken but not completed have for one reason or another been abandoned. He has continued during the past winter to fill up gaps in the history and has during the summer practically completed the part dealing with the Colonial period, which will amount to about 60,000 words. He expects to devote the greater part of his time during the coming winter to completing a few sections which require further study and to revising the whole. The work will probably fill one volume and should be finished in the spring of 1914.

Division XI.—Federal and State Finance, Including Taxation.

Professor Gardner has again been prevented by illness in his family from doing much writing during the past year. He reports as follows on the monographic work: The following have been published since September 1, 1912:

The finances of Vermont. By Dr. Frederick A. Wood. Studies in History, Economics, and Public Law, edited by the Faculty of Political Science of Columbia University, vol. LII, No. 3, pp. 147, 1913.
Repudiation of State debt in Texas since 1861. By Professor E. T. Miller, of the University of Texas. The Southwestern Historical Quarterly, October 1912. (This is a portion of Professor Miller's study of the financial history of Texas, the publication of other portions of which was noted in the report for 1911.)
Financial history of California. By Mr. W. C. Fankhauser. (This monograph, noted as completed in manuscript in the report for 1912, is now in press.)

The following monograph has been completed since the last report, but has not been published:

Financial history of New York. By Mr. Don C. Sowers. To be published by Columbia University.

The following monographs are substantially completed:

Financial history of Illinois. By Mr. Robert M. Haig. To be published by Columbia University.
Financial history of Texas. By Professor E. T. Miller, of the University of Texas. (For portions published, see above and the Report of 1911.)
Financial history of Virginia. By Mr. Edgar Sydenstricker.

Studies upon which substantial progress has been made and which are now being carried through to completion:

Financial history of North Carolina. By Professor W. K. Boyd, of Trinity College, Durham, N. C. (Substantially complete to 1860.)
Financial history of Pennsylvania. By Dr. Clyde L. King, of the University of Pennsylvania, and Dr. Ralph E. George, of Lehigh University.

Studies, portions of which have been completed but upon which nothing has been done during the past year, and of the completion of which there is no immediate prospect:

Financial history of Tennessee. By Professor St. George L. Sioussat, of Vanderbilt University.
Financial history of New Jersey. By Professor Edgar M. Dawson, of the Normal College of the City of New York. (Professor Dawson has been compelled to abandon this work.)
Comparative study of the financial development of certain of the larger cities of the United States. By Professor Oliver C. Lockhart, of the State University of Ohio.
Financial history of Michigan. By Professor Wilbur O. Hedrick, of the Michigan Agricultural College.

Dr. Clyde L. King has during the past year associated with himself in the study of the financial history of Pennsylvania Dr. Ralph E. George, of Lehigh University.

Division XII.—The Negro in Slavery and Freedom.

Mr. Alfred Holt Stone reports from his plantation in Dunleith, Mississippi, that while he is still obliged to stay in the South in order to look after his property interests, the prospects of his resuming

active work on his division are considerably better than they were a year ago. Dr. James M. Wright has finished his study of the free negro in Maryland and Professor E. P. Puckett has rewritten and enlarged his essay on the Free Negro in Louisiana.

The following monograph has been published:

The Negro in Pennsylvania. By Richard R. Wright, Jr., pp. 250, 1912.

INDEX OF STATE DOCUMENTS.

Miss Adelaide R. Hasse reports that no volumes of the Economic Index have been issued during the year. New Jersey, the twelfth in the series, is about ready for the printer and work on Pennsylvania is well advanced. A good deal of work has been done on other States, notably South Carolina.

The following is a complete list of the States of which indices have been published, with the year of publication:

California	1908
Delaware	1910
Illinois	1909
Kentucky	1910
Maine	1907
Massachusetts	1908
New Hampshire	1907
New York	1907
Ohio	1912
Rhode Island	1908
Vermont	1907

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. Davenport, Director.

The principal advances of the year have been in demonstrating a chemical basis for sex-differentiation, a subject to which we have paid special attention during the past few years; in opening up new types of inheritance-behavior in the œnotheras; in completing the demonstration of duplicate determiners for a single character in *Bursa;* in discovering the first case of sex-limited heredity in plants; in demonstrating the method of inheritance, in man, of tendency to periodic "fits" of temper and certain other elements of the hysteria-complex.

STAFF.

The Director divided his time for research between breeding experiments with poultry, canaries, sheep, goats, and cats, and the study of data secured by trained field workers on certain points in human heredity. On the occasion of attending a meeting of the American Breeders' Association at Columbia, South Carolina, he was able to make additional studies on the heredity of skin pigmentation in negro-white crosses, the results of which are incorporated in a memoir on this subject about to appear as Publication No. 188. Dr. G. H. Shull has found that the time demanded for his experimental work has prevented him from completing the Burbank manuscripts and it has been arranged that he shall devote a season to the completion of that manuscript. He will probably be absent from the Station for twelve months. Dr. Shull's green-house assistant, Mr. Leo Macy, is to be given leave of absence for further study, and Mr. C. W. Crane, who has been in training during the present year, will take his place. During this summer, Dr. G. H. Shull also was assisted in his fertilizations and records by Mr. William F. Friedman. Dr. J. A. Harris was absent during several months of the winter working at the Desert Laboratory. Meanwhile, his three assistants and computers were preparing data from the harvest of the preceding season. His work is largely of a statistical nature and has included the rearing and observation of scores of thousands of seedlings. Dr. R. A. Gortner has had charge of the biochemical laboratory, and besides continuing his studies in melanin has cooperated in various researches with Doctors Banta, Blakeslee, and Harris. Dr. A. M. Banta has had charge of the experiments with the cave organisms and has made other studies on the relation of organisms to light, notably the production, by selection, of races that differ in responsive-

*Situated at Cold Spring Harbor, Long Island, N. Y. Grant No. 860. $91,854 for investigations, maintenance, and construction during 1913. (For previous reports see Year Books Nos. 3–11.)

ness to light. Dr. A. F. Blakeslee, of the Connecticut Agricultural College, Storrs, has worked at this Station, as Research Associate, on sex and mutations in molds, in part in collaboration with Dr. R. A. Gortner.

Of the more temporary appointments, Mr. H. D. Goodale resigned in January to accept a position as research biologist in the Massachusetts Agricultural Experiment Station, Department of Poultry Husbandry. Dr. G. C. Bassett began in July, as a guest of the Laboratory, his work on alcoholism and mental degeneracy in rats.

To relieve the Director of details of accounts, supervision of workmen, and purchase and care of supplies, the office of Superintendent was created and Mr. G. H. Claflin began work in that capacity in February 1913.

REPORTS ON INVESTIGATIONS IN PROGRESS.

CHEMICAL BASIS AND HEREDITY OF SEX.

Sex in Molds, by A. F. Blakeslee.

The principal new work upon sex has been with molds, by Dr. A. F. Blakeslee, and with *Lychnis*, by Dr. Shull. Dr. Blakeslee's efforts to discover which of the sexual races of mucors, provisionally designated respectively as plus (+) and minus (−), is actually male and which female met with success. He had previously discovered that among the white molds the majority of the species are diœcious, with the male and female races indistinguishable from each other except by a frequently greater vegetative luxuriance of the one race provisionally called plus (+) over the other provisionally called minus (−). Since the gametes formed by these plus and minus races are morphologically equivalent and the offspring are borne and nourished equally by the two sexes, no means were at hand to decide which of the two sexual races was actually to be considered male and which female. However, certain hermaphrodite species were known in which the gametes are regularly unequal. It was thought that if one of the two sorts of races could be induced to show a sexual reaction with the larger or female gamete of the hermaphrodite and the other race with the smaller or male gamete it would be possible to replace the provisional signs + and − by male (♂) and female (♀) or *vice versa*. Only two species have been found that show the sexual reaction desired. The difficulties in technic involved are great, but these have been satisfactorily overcome and it has been definitely determined that the plus (+) race shows a sexual reaction with the smaller or male (♂) gamete, while the minus (−) race shows a reaction with the larger or female (♀) gamete. The vegetatively more luxuriant race, therefore, may be considered female and the less luxuriant race male. Additional facts obtained by growing cultures in large quantities seem to warrant formulating the general law that whenever

a difference exists in vegetative luxuriance between the two sexes in these forms it is always the female (♀) that is the more luxuriant.

The general results of the foregoing investigation were presented in a paper read by Dr. Blakeslee at the Cleveland meeting of the American Association for the Advancement of Science and are summarized in the issue of *Science* for June 6 by Dr. Blakeslee. The detailed results are to be incorporated in a paper now in preparation on "Sexual reactions between unlike species."

The argument in the foregoing publications is based upon the sexual character of unequal gametes in heterogamic hermaphroditic species. Since the sexual nature of these gametes has been recently called in question by Gruber and Atkinson, Dr. Blakeslee found it necessary to make a careful study of all the heterogamic forms available, following the process of sexual reproduction in living material—a procedure that apparently has not been satisfactorily attempted before. The results are given in a paper by Dr. Blakeslee published in the April issue of the Mycologisches Centralblatt and seem amply to warrant the line of argument already mentioned.

Dr. Blakeslee had previously shown that if a given diœcious species (Mucor V) be taken as a standard, its male (♂) race will show a sexual reaction with the female (♀) races of all the other diœcious forms under cultivation, but not with the other male (♂) races. Conversely, its female (♀) race shows a sexual reaction with male (♂) races only. The conclusion seems unavoidable that all the female (♀) races have something in common which elicits a similar response from the male (♂) race of Mucor V and *vice versa*. That this common element is of a chemical nature and therefore demands a chemical study is a natural inference. There are no other forms known that seem to offer a suitable subject for such a chemical investigation. Other available organisms in which there are separate male (♂) and female (♀) individuals show a sexual division of labor in that the female (♀) has the feeding function predominatingly developed, either furnishing food to the egg or to the developing offspring. Any chemical differences, therefore, between male (♂) and female (♀) individuals or between sex-cells found in these forms would have no necessary connection with the sex differences, but rather would be connected with the one-sided nutritional function of the female (♀) sex. In the mucors, however, the sex-cells are morphologically equivalent and the male and female plants take an equal share in feeding the developing offspring.

Chemical Differences between the Sexes, by A. F. Blakeslee and R. A. Gortner.

Starting with the hypothesis that sex difference might be a difference in the proteins of the two sexes, a beginning was made with the blood tests for proteins. As yet work has been done only with

the precipitin reaction. Considerable time has been consumed in acquiring proper technic for the preparation of the mold proteins and in overcoming the difficulties due to the fact that the "press-saft" (expressed juices) which they wished to inject is more or less toxic. However, rabbits were immunized to the plus (+) and minus (−) races of two species of mucors. In both cases, the plus (+) "press-saft" when mixed with the plus (+) immune serum gave a stronger precipitate than the minus (−) "press-saft" with the plus (+) serum, and *vice versa*. The difference shows only in the higher dilutions, but this is what one would expect upon assumption of the presence of species proteins common to both sexes of a given species in addition to a separate sex protein or proteins—the large amount of precipitate caused by the species proteins making the difference due to the sex proteins. While the results so far obtained will not yet warrant the assertion that Dr. Blakeslee and Dr. Gortner have found a protein responsible for sex, still the tests, in so far as they go, are all consistent with such a conclusion. Furthermore, there is some slight evidence that the same sex proteins occur in different species. This would be a natural inference from the fact that the plus (+) races show sexual reaction with minus (−) races of other species and *vice versa*.

Sex in Lychnis, by George H. Shull.

In his studies on the heredity of sex in *Lychnis* Dr. Shull has discovered a sex-limited character—the first that has been described for plants. This character is broad-leaf, the determiner for which is, it is concluded, associated with the determiner for femaleness. In making this study 60 pedigreed families of *Lychnis* were grown to test completely the genotypic character of individuals making up the second generation descended from a cross between a normal broad-leafed female and a narrow-leafed male. The F_2 family in question consisted of 32 broad-leafed females, 11 broad-leafed males, and 6 narrow-leafed males. The analysis has had the expected result and has shown that there were really four kinds of individuals in the F_2 generation, namely, 16 homozygous broad-leafed females, 16 heterozygous broad-leafed females, 11 heterozygous broad-leafed males, and 6 homozygous narrow-leafed males.

These results accord exactly with expectation on the basis of an assumed association of the determiner for broad leaves with the determiner for femaleness and of a double sex- (femaleness) determiner in the female and a single one in the male. The result thus serves to confirm Dr. Shull's conclusions derived from the breeding of hermaphrodites, that the female is homozygous, while the male and also the hermaphrodite are heterozygous for the sex-determiner.

One result expected by Dr. Shull has failed of realization, so that a perplexing situation has been created which, however, in no wise invalidates the conclusions to be derived from the facts given above. It was predicted that in the crosses between heterozygous females and narrow-leafed males there would appear a new type—narrow-leafed females. This prediction has not been fulfilled. Although in the past Dr. Shull's cultures of *Lychnis* have contained an average of about 62 per cent females, the 37 matings between broad-leafed females and narrow-leafed males whose offspring have been grown this year have produced only 14 females in nearly 2,700 individuals, or a little over 0.5 per cent. Eight of these females occurred in a single family in which no narrow-leafed plants were to be expected, because the mother was homozygous for broad leaves. Only two females occurred in families which also contained narrow-leafed plants, and these two chanced to be broad-leafed. One narrow-leafed female did appear, but in a family in which it was not due theoretically to appear. This plant differed so profoundly from all his other specimens of *Lychnis* that it is considered likely that it will be found to be a mutant of an interesting nature. To offset the 31 families in which not a single female occurred, in four families there was not a single male or hermaphrodite. Three of these families were the total progeny of a single hermaphrodite crossed upon three unrelated females.

A mating between a heterozygous, broad (narrow) female and an unrelated broad-leafed hermaphrodite has produced a progeny consisting of 67 broad-leafed females, 15 broad-leafed hermaphrodites, and 9 narrow-leafed hermaphrodites, showing that this unrelated hermaphrodite parent was a heterozygote in the broad-leaf character—an independent origin of this interesting mutation. The males of any race of *Lychnis* might have the broad-leaf determiner lost from the male determiner, and such a condition could be discovered only when a female is found in which there has been a similar mutation in a female determiner. Appreciating the importance of this possibility in interpreting the origin of the first narrow-leafed male, Dr. Shull has made crosses between the males of all his independent races of *Lychnis* and heterozygous females to ascertain how generally the determiner for maleness is lacking the broad-leaf determiner.

Dependence of Secondary Sex-Characters on the Germ-gland in Poultry, by H. D. Goodale.

Dr. Goodale continued the work described in the last Year Book, page 87, both at this Station and at Amherst. Castrated drakes do not assume the summer plumage. All males which assumed the summer plumage, although previously castrated, have been dissected and, in each case, a greater or less amount of testicular material has been found. It has not been deemed desirable, at the present, to kill those which

have not assumed the summer plumage. Among the females there was one individual, castrated late last fall when four weeks of age, that is particularly interesting for two reasons. First, she has never developed the duck's voice. Her usual voice is quite like that of the drake, and even when especially stimulated, she only succeeds in producing a sort of half quack. This bird did not assume the entire plumage of the male, a few brown feathers remaining in the breast, but after a molt early in the summer assumed the *summer* plumage of the drake. Just at present she is undergoing a second molt and this time is assuming the normal breeding-plumage of the male. This is the first case that Dr. Goodale has found to behave in this way. Another duck developed the plumage of the male perfectly, but, although molting, did not take on the summer plumage of the male.

In respect to his experiments with fowl Dr. Goodale reports as follows:

Altogether, I have had eight pullets which have developed the male plumage to a greater or less extent. One individual which was castrated last summer was reported as having started to develop the male's plumage, and then after a time was found to have begun reverting to the female's. An examination was made, and it was found that there was a bit of ovarian tissue attached to the posterior side of the oblique septum. There were also three ova, each about 10 mm. in diameter, lying on the original site of the ovary. The ovarian tissue attached to the transverse ligament was removed, but the other left in place. During the present summer it was observed that this bird again began to develop the male plumage, and, to all appearances, the complete male plumage would have eventually replaced the female. On autopsy it was found that all trace of ovarian tissue was lacking.

Two other females developed the *complete* plumage of the male, but the combs and wattles still remain small. This plumage includes a cock's tail which was lacking in the first bird in which these results were obtained. Except for the small comb and wattles, these birds are much better specimens than the original.

Observations have been continued on the two capons which were castrated in the spring of 1911. Their combs and wattles remained small for 18 months, but after this period they grew considerably, and now have reached a size about that of a Brown Leghorn pullet just before she commences to lay. Early in the spring, when 2 years old, they were observed to crow, although this reaction occurred only a few times. In the absence of normal males, they tread the hens. It is important to note that these responses developed late in life and that externally the birds were capons for over 18 months, or half again the usual age for keeping capons.

MUTATIONS AND ABERRATIONS.

No student of evolution by experimental methods can doubt the importance of mutations. Our work has shown that they are sometimes due to irregularities in the behavior of the chromosomes during maturation, and the hypothesis seems warranted that they are always

so due. However, through lack of a cytologist, we have not been able to test this hypothesis upon all of our mutants. We have merely been able to observe their origin and inheritance but not yet to induce them nor to study their cytological basis.

Variegation in Lychnis and the Chlorophyll Factors, by G. H. Shull.

In 10 families derived from crosses between sibs, albinos have constituted almost exactly one-fourth of the offspring, the total numbers being 713 green to 240 albino. As many other sib-crosses in the same stock have produced only green offspring there can be no doubt that this result is due to the existence of a fundamental Mendelian factor for chlorophyll-production.

Two light-green races of *Lychnis dioica* have been discovered, each of which is recessive to the ordinary dark-green strains. When members of these two light-green strains are crossed together their F_1 offspring are uniformly dark green. In the F_2, which has been grown extensively this year, the light-green types reappear in approximately the expected ratio, 9 dark : 7 light. It is not certain what should be the result when the determiners for both of these pale races are absent, and it is possible that this ratio should be 9 : 6. Extensive back-crossing upon the pale types must decide this question, and the necessary crosses have been made for this purpose.

The study of several kinds of variegation has been continued, and material has been secured for testing the results of breeding from variegated males possessing a type of variegation which has proved to be readily transmissible through the seed-parent, but whose effect through the pollen-parent is as yet unknown. A golden variegation discovered two years ago was found to be slightly inheritable through the male as well as strongly inherited through the female.

Ascidia in Fraxinus, by G. H. Shull.

In continuation of his experiments recorded at page 88 of Year Book No. 11, with the pitcher-leafed ash, Dr. Shull reports that the two pedigrees representing crosses between a normal and a pitcher-leafed ash, and between two abnormal (*i. e.*, pitcher-leafed) ash trees, have together produced about 40,000 leaflets this year, each of which has been carefully examined for pitchers, and its position and the character of the ascidium, if present, recorded. The cross between normal and abnormal, which produced no abnormal leaflets during the first season following the germination of the seeds, has this second season displayed ascidia on 26.9 per cent of the trees, and in the family produced by crossing two ascidiate trees pitchers have developed on 58.7 per cent of the trees. A still larger percentage of abnormal trees may be expected as they grow older and become more vigorous, and it will not be surprising if in the end there should appear

approximately the 50 per cent and 75 per cent, respectively, which might be expected on the assumption that the ascidia are produced by a dominant Mendelian determiner.

Abnormalities in Seeding Beans and in Fruits of Passiflora, by J. A. Harris.

These studies are being continued as outlined in previous reports and are being lined up with the selective elimination, fertility, and physico-chemical studies. Material progress in the experimental control of the occurrence of certain of these phenomena by physical and chemical means has been made during the year.

Mutations in Mucors, by A. F. Blakeslee.

The chief work planned by Dr. Blakeslee was to induce the production of mutations in mucors by chemical or other forms of stimulation. He was thus led to make extended preliminary studies and to devise new methods. His report on this part of the work is as follows:

A standard medium was considered necessary that could be taken as representing a favorable or normal substratum, and some 308 different combinations of nutrients (natural and synthetic) were tested. It was discovered that the mucors were unlike the green molds (*Penicillium*) in that they would not grow well on liquid media nor upon synthetic media in which the necessary elements were supplied in relatively simple chemical substance. An agar nutrient with 2 per cent dry malt extract, 2 per cent dextrose, and 0.1 per cent meat peptone was eventually adopted as a standard medium sufficiently near the optimum value for most forms investigated and as nearly constant in chemical composition as any tested upon which the molds would thrive.

Sexual reproduction in the mucors demands in general the optimum cultural conditions, and the abundance of zygospore formation on a given substratum has been used accordingly as an index of its cultural value. Phycomyces is one of the most demanding forms so far as its requirements for zygospore production is concerned and in consequence is the species which has been most used in the nutrient tests. Peptone, although the usual form in which nitrogen is supplied in culture media, was found to have a slightly inhibitory action on zygospore formation. Meat peptone seemed to be less toxic than either peptone from egg-albumen or Witte's peptone. Nutrients containing peptone which would allow only a poor growth with entire suppression of zygospores could be changed into optimum substrata with luxuriant zygospore production by inoculating them with bacteria either before or at the very time of planting the sexual races of the mold. The subject needs further investigation before publication. It is not unlikely, however, that by tryptic action of the bacteria the peptone is further broken down into a condition less toxic and more available to the mold. This seems to be the case in the preparation of media upon which the leprosy organism has recently been successfully cultivated. The action of bacteria may explain why a decoction of horse dung has been found to be one of the best substrata for zygospore production.

A standard medium having been decided upon, it became necessary to provide against contamination from germs of foreign species in the pedigree cultures. An isolated culture room containing a pure-culture chamber,

within which was placed an inoculating box—all of which were sterilized before using—reduced contamination during inoculation to a minimum, as shown by the presence or absence of growths in Petri-dish cultures kept exposed while all inoculations were in progress. A record of two hours' inoculating, followed the next day by one hour's inoculating, without a single viable germ falling upon an exposed Petri dish 10 cm. in diameter, shows the value of the precautions taken. Contamination is likely to occur in Petri dishes *after* inoculation, and, to avoid this, "roll tubes" were devised from 0.5 gallon cylindrical specimen jars and were used throughout the investigation whenever "separation cultures" were made to obtain growths from individual spores. A note on this new method of separation cultures is being prepared for the journal "Phytopathology."

The preliminary work in formulating a standard medium and in devising means to prevent infection from outside sources has consumed considerable time, but has been necessary to insure accurate and credible results.

Before testing the influence of external stimuli upon the possible formation of mutations, all of my 24 mated diœcious species as well as 10 hermaphroditic forms (a total of 58 cultures) were separated out, so that each strain investigated could have a single spore as its origin. A preliminary investigation of the growths resulting from single spores of these forms showed that species in particular—an hermaphroditic form—that gave such a relatively great variability in its progeny that it has received most attention. I have cultures of this species from four different localities and have examined separately the growths from individual spores to the numbers indicated from the following sources:

Cambridge, Massachusetts	13,740
Geneva, Switzerland	1,925
Daytona, Florida	364
Waverly, Massachusetts	6,943
Total colonies examined	22,971

Of these 22,000 and more individual colonies examined, those that seemed different in appearance from the normal type have been isolated to the number of some 25 or 30. Among the aberrant characters observed are absence and increase or decrease of zygospore production, peculiarities in color, density, and rapidity of mycelial growth, differences in height of sporangial filaments, the almost exclusive production of yeast-like cells in place of a filamentous mycelium, and the production of a filamentous mycelial growth devoid of sporangia. Some of these variants are surely temporary conditions, for they eventually tend to revert to the normal type. Others may be more permanent, but have not been sufficiently investigated. All, however, tend, partially at least, to reproduce the new characters and some have for several sporangial generations kept their peculiarities in gross cultures during the few months it has been possible to propagate them. Many of them would undoubtedly be described as distinct species by specialists in the group. Of these and other molds, several hundred test-tube cultures have been made up with nutrient, to which various poisonous chemicals have been added, but time has not yet admitted a test of the effect of these chemical stimuli on the offspring. Enough has been done, however, to show the extreme lability of at least a single species under normal conditions of cultivation.

Mutations in Poultry, by C. B. Davenport.

While mutations hitherto observed in mammals (Castle) and insects (Morgan) are usually due to the loss of a determiner, so that the new condition is "recessive"to the former, in poultry the reverse is frequently the case. Thus all modifications of the feet—extra toes, syndactylism, absence of toe-nails—are dominant over the typical condition. It is as though some extra determiner had entered the mechanism and caused an irregularity of the developmental processes in the feet. Also the absence of tail is a positive character; there is an inhibitor to the development of this organ. One of the most instructive instances of this sort of mutation is seen in the abnormalities of feathering in poultry. Apparently all parts of the outer covering of a bird had primitively the potentiality of producing feathers. But secondarily this power has been lost in specific areas. The shanks are devoid of feathers in many races, and when an individual of any such race is mated with one of a shank-feathered race the offspring are clear-shanked or nearly so; the inhibitor is derived in the progeny from the clear-shanked parent, but the inhibition is not perfect. I was able to get some bare-necked poultry and found, on crossing them with the ordinary type, that half of the offspring have naked necks. Here again the absence of feathers is due to a specific inhibitor to the growth of feathers on the neck. Indeed, it is probable that there are at least two inhibitors (for different areas of the neck), since two types of "bare neck" occur.

BIOCHEMICAL PROCESSES IN HEREDITY.

The internal factors that direct the course of development are the determiners; and it is by virtue of the fact that we can—through crossing—combine determiners at will, that we are able to make new and improved breeds. But between the determiners in the germ-cells and the adult characters is a great gap and it is this gap that chemical studies carried on here seek to fill.

Chemistry of Ontogeny, by R. A. Gortner.

Dr. Ross A. Gortner has planned an extensive investigation of the chemistry of ontogeny. For this work the adjacent State fish-hatchery affords excellent facilities, for the use of which we are indebted to the State Commissioners and to Mr. Charles H. Walters, foreman. Trout eggs in five stages of development were used to ascertain whether the chemical compounds that are present in the egg enter the growing tissues in the form in which they are laid down in the egg or whether there are synthetic changes taking place so that the material which is present in the egg is used, not in its original form, but in a modified condition. It seemed to Dr. Gortner that synthetic action must take place, for otherwise we must think of

the egg proteins, the ovalbumen, ovomucoid, ovolobulin, etc., as containing not only all of the amino acids necessary for the formation of such complex proteins as the hemoglobin, but also that each amino acid is present in the egg in *exactly the quantity which will be later needed by the growing organism.*

His results show conclusively that synthetic action *does* take place, that the simpler mon-amino acids are in some manner transformed into the more complex constituents of the cell nucleus. Aside from this synthetic action it was found that there was a selective utilization of the nitrogen fractions which were "burned" to furnish the energy of development (Entwicklungsarbeit). Only 25 per cent of the expected "amide nitrogen" was utilized, only 50 per cent of the expected "arginine nitrogen," only 75 per cent of the expected "lysine nitrogen," none of the "cystine" or "histidine nitrogen," while the deficit caused by the non-utilization of the basic nitrogen was filled by the elimination of the mon-amino nitrogen far in excess of the expected quantity (88.30 per cent, expected 57.65 per cent).

Pigment-forming Processes and their Control, by R. A. Gortner.

Dr. Gortner has continued his study of the melanins. He reports:

In the study of the melanins considerable additional work has been done, but only one paper has been completed. Inasmuch as it is practically a certainty that the melanins are formed by the action of tyrosinase on some chromogen, the nature of the chromogen involved becomes of paramount importance. The melanin which I have isolated from black wool is of a protein nature, and in this instance the chromogen must involve a protein or a peptide. In order to test whether this chromogen is a part of the normal keratin structure or whether it is a special body, elaborated solely for the purpose of pigment formation and not utilized in the hair structure when there is a lack of enzyme action (albinos) or when there is an inhibition of oxidase action (dominant whites), I have made a complete analysis of the nitrogen ratios in both black wool and in white wool taken from the same animal. The results of the analyses do not absolutely prove either hypothesis, but they tend to support the belief that the chromogen is not present in the unpigmented wool structure, but that it is introduced in an oxidized form into the black wool solely as a foreign substance.

Aside from this conclusion the work was of interest as being the first analysis on record of pigmented and unpigmented hair structures taken from the same animal, and also as furnishing confirmatory evidence for my previous contention that hydrolysis with strong mineral acids breaks down the melanin molecule.

Relationship between Morphological Characters and Chemical Composition, by J. A. Harris and R. A. Gortner.

The analysis of the physiological causes of variation has been one of the chief phases of Dr. Harris's work since coming to the Station. Studies of fertility and of selective elimination have both furnished the most convincing evidence of the association of physiological with morphological variations. Of course, the suggestion follows at once

that these physiological differences can be ultimately reduced to physico-chemical terms. One is led, therefore, to expect an association between the structure of organs and the physico-chemical properties of their cellular juices. These problems, which have up to now been treated at this Station only from the physiological standpoint, are now being studied from the chemical side in collaboration with Dr. Gortner. It is as yet too early to justify any generalizations, but the results are most encouraging.

Studies of osmotic pressure, electrical conductivity, and mean molecular weight in the juices of normal and structurally aberrant *Passiflora* fruits seem to show conclusively that there the distinguishing morphological features are associated with differences in the physico-chemical properties of the cell-sap. Thus, the juice of abnormal fruits has a higher osmotic pressure than that of normals; and the average molecular weight of the substances in solution in the plant-sap is, apparently, lower in the abnormal fruits. This study has an especial value as a first step in the analysis of the factors involved in morphological characters of the fruit.

Dr. Harris and Dr. Gortner also made a joint study of the records furnished by various experiment stations as to the relation of weight of the sugar beet and the composition of its juice. They find that as the weight of the sugar beet increases the total solids, sucrose, and percentage purity (*i. e.*, the ratio of sucrose to 100 parts of total solids) fall rapidly.

Inhibition of Pigmentation, by A. M. Banta and R. A. Gortner.

Dr. Banta and Dr. Gortner have continued their experiments with those phenols that inhibit the reaction tyrosinase + tyrosin *in vitro* upon eggs and larvæ of the little salamander, *Spelerpes*, reported in the last Year Book, page 84.

The effects of the inhibitory compounds on pigmentation are still visible in the few larvæ which are still alive, after having been removed from the influence of the drugs for nearly a year. Dr. Gortner draws the interesting conclusion that it seems probable, were it possible to secure compounds which are at the same time non-toxic and which inhibit the action of tyrosinase or tyrosin, that permanent "dominant whites" could be produced. Dr. Banta repeated last year's experiments on *Spelerpes*. With the aid of last year's experience the proper strength of solution for *Spelerpes* was closely determined and correspondingly more striking results were obtained. When the pigmentless larvæ are placed in 0.025 per cent orcinol or resorcinol three days before the pigment normally begins to form, pigmentation is almost entirely inhibited for as long a time as the larvæ retain the inhibiting substances in their pigment-producing tissues. Unfortunately the larvæ can not be kept in these solutions

with safety for more than 12 or 15 days. After removal the larvæ develop more or less pigment, although up to that time they remain almost without pigment; but they do not assume the normal type of pigmentation.

Dr. Gortner and Dr. Banta attempted to modify the pigmentation of the vinegar fly in the same way as that of *Spelerpes*. *Drosophila* offers the advantage that the inhibitors may be placed directly into the food (crushed banana) and thus gotten into the animal's digestive tract and presumably into its tissues during all stages of its active life. Some of these flies have been reared, carefully isolated, through twelve generations on banana containing known percentages of orcinol and resorcinol. The third generation showed marked reduction in pigment in many of the orcinol and some of the resorcinol "lines," and later generations have shown a slight further reduction. The modified forms show reduction in intensity of color of the areas pigmented with black pigment and a reduction in the extent of the pigmented areas, particularly in the extensive black region at the end of the abdomen in the male. Further breeding-tests ought to show whether this is a modification produced ontogenetically in each generation or one which may have hereditary significance. It has not arisen through selection, as selection has been avoided in the experiment.

Reactions of Rabbits to Spores of Molds, by A. F. Blakeslee and R. A. Gortner.

In their investigation of the main problem of the chemical nature of sex, Dr. Blakeslee and Dr. Gortner have obtained results in three side-problems—the effect of injection of mold spores into an animal, the influence of a vegetable protein in the food upon the serum of an animal, and the toxicity of expressed mold juices.

They found that spores of *Cunninghamella* when injected intravenously will kill a rabbit (four instances). Post-mortem examination demonstrated the presence of germinated spores in the lungs. This mold is a tropical form growing readily at rabbit temperature and its growth may have caused death by mechanically interfering with the functions of the organs infected. Mucor V is incapable of growing at body-temperature and its spores were used in a new series of injections. Rabbit No. 5 received intravenously, at appropriate intervals, doses averaging about 500,000,000 spores of the minus (−) race of Mucor V. Rabbit No. 55 was similarly treated with plus (+) spores of the same species. For the twenty-fifth injection, rabbits Nos. 5 and 55 received 800,000,000 spores respectively of the minus (−) and plus (+) spores, and at the same time two control rabbits previously untreated were similarly injected with like doses of spores of the plus (+) and minus (−) sexes respectively. Separation cultures made from loops of blood taken from these rabbits at

half-hourly, hourly, and eventually at less frequent intervals showed that viable spores disappeared from the blood-stream in about 48 hours, but no more rapidly in No. 5 and No. 55 than in the control animals that had not previously been treated. A similar experiment was performed with mixtures of spores with the sera of the treated rabbits *in vitro* and confirmed the conclusion that rabbits are incapable of forming an antibody in the blood which will dissolve these mold-spores. They are capable, however, of producing cytolytic antibodies that will dissolve red blood-corpuscles and certain other animal cells, and it was hoped a similar cytolysin might be developed for spores and that the action might be sexually specific.

In attempting to use the ordinary bread mold (*Rhizopus nigricans*) in getting immunity reactions with rabbits they discovered that this common species is extremely poisonous. The extract from 0.04 gm. of dried filaments is sufficient to kill a 3-pound rabbit. The toxin which has been obtained by Dr. Gortner by precipitation with alcohol resists peptic digestion, also the action of boiling temperature at least for 5 minutes. It is therefore not a tox-albumen. It is soluble in water, but is non-dialyzable. The minimum fatal dose intravenously is about 1 part to 225,000 parts of rabbit by weight. The enormous strength of the *Rhizopus* toxin may be shown by a comparison with some recently investigated organic toxins. White and Avery have found that the minimum fatal dose of the poisonous substance from the tubercle bacillus is one part to 15,000 parts of body-weight, while the toxic cleavage product from edestin kills in doses of 1 part to 40,000 of body-weight. Alsberg's penicillic acid, isolated from *Penicillium*, has a minimum fatal dose in subcutaneous injections of 1 part to 4,700 of body-weight. The toxicity of the *Rhizopus* poison appears, therefore, to be 5.5 times that of the tubercle bacillus, 15 times that obtained from edestin, and 45 times that of penicillic acid. Dr. Blakeslee has previously made a special study of the distribution of *Rhizopus* and finds it occurs throughout the world and is almost certain to appear as a spontaneous infection of bread and similar substrata rich in carbohydrates, whenever the proper temperature and moisture requirements are observed. Its possible relation to those diseases of unknown origin, such as pellagra and the horse-disease and the corn-stalk disease of the middle west, which have been attributed to infected food, is not being overlooked.

THE MODIFYING EFFECTS OF CAVE CONDITIONS.

Dr. A. M. Banta's experiments with cave material are being continued. The mud minnows (*Umbra limi*) are showing some further depigmentation; *Cambarus bartoni*, a non-cavernicolous crayfish, likewise shows a progressive loss of pigment; some of the salamander larvæ in the cave during the present year have less pigment than

those reported on a year ago; and a lot of wood-frog larvæ reared in the cave have developed very little pigment. But the most interesting material is the amphipod *Eucrangonyx gracilis*, an almost pigmentless form of which lives in caves in central Indiana, while the normally pigmented form is abundant in the surface streams in the same region. Series of these two forms have been placed both in the cave and in the vivarium and interesting results are hoped for.

During the past winter a short time was spent in the cave region in Indiana and numerous experiments were made on the light and tactile reactions of the two forms of the above-mentioned amphipod. In accord with the results of earlier experiments with an eyeless cave isopod and its near outdoor relative, the cave amphipod was found to be less responsive to light and more responsive to tactile stimulation than its outside relative.

VARIOUS PROBLEMS IN HEREDITY.

Inheritance in Shepherd's Purse, by George H. Shull.

The discovery by Neilsson-Ehle at Svalöf of duplicate determiners, for some of the characters of certain grains, has led to the discovery of a similar sort in animals and plants and even in man. Dr. Shull reports another case in a character upon which he has been at work for some time and whose behavior appeared at first erratic. The cultures of the present year have fully confirmed his view that there are duplicate determiners, each of which, independently of the other, is capable of producing the triangular type of capsule characteristic of *Bursa bursa-pastoris*. In support of this proposition the following facts have been demonstrated:

(*a*) All individuals of the F_1 families formed by crossing *B. bursa-pastoris* with *B. heegeri*, have triangular capsules.

(*b*) In all F_2 families there is an approximation to the ratio of 15:1 between plants having triangular capsules and those having top-shaped capsules.

(*c*) When F_2 families having triangular capsules are self-fertilized, three kinds of F_3 families are produced, namely, (1) those in which all of the individuals have triangular capsules; (2) those in which the individuals having the two kinds of capsules occur in the ratio 15:1; and (3) those in which the two kinds of plants appear in the ratio 3:1.

(*d*) In the F_4 the results differ according to the type of F_3 family from which plants of the dominant type are used for breeding: (1) The members of those F_3 families which contained only plants with triangular capsules produce only triangular capsules again; (2) when the parents are triangular-capsuled plants from an F_3 family in which a 15:1 ratio occurred, the F_4 families fall into the same three groups as the F_3 families; (3) from the dominant indi-

viduals of an F_3 family in which a 3:1 ratio occurs, only two kinds of F_4 families arise, namely, with triangular capsules only, or with the two kinds of capsules in the ratio 3:1.

(*e*) Extracted dominants in an F_3 family displaying a ratio 3:1 are not the same genotypically as the original type used in the crosses, though indistinguishable from it by simple inspection. Crosses between these extracted dominants and *heegeri* have yielded only F_2 families with a ratio 3:1, instead of 15:1, as found in the original F_2 families.

A new and unequivocal case of duplication of determiners is thus added to the very few which have been found in other plants, as the results here summarized are supported by about 140 pedigreed families and can find no other logical interpretation. There is some indication that duplicate determiners exist for one of the rosette characters also in *Bursa* as well as for the distribution of sterile flowers on the racemes, but these cases require further investigation.

Hybrids in Oenothera, by G. H. Shull.

Dr. Shull has continued his hybridization of *Oenothera lamarckiana* and the several biotypes of *Oe. cruciata*, and the progeny are truly remarkable in their complexity.

The first generation hybrids between *lamarckiana* and the biotypes of *cruciata*, and between the several possible pairs of the biotypes of *cruciata* which were reported last year as consisting of polymorphic progenies and strikingly unlike reciprocals, have been repeated, together with parallel series in which another strain of *lamarckiana* and a *rubrinervis* were used respectively in the place of the *lamarckiana* involved in the original series. The 22 types found last year have all been confirmed in this year's cultures and several new types have been added, the corresponding forms from the two new series being indistinguishable from those originally secured. The second generation has been grown extensively and more than half of the possible combinations of F_1 types with the parents and related hybrids have been studied, and additional crosses have been made to fill partially the gaps still remaining. In the crosses between the biotypes of *Oe. cruciata* the results are relatively simple, the most striking features of the situation being the facts: (*a*) that more than 100 F_2 combinations have added only one new type in addition to the occasional aberrant individuals which one is apt to meet in pure-bred as well as hybrid stocks; (*b*) that in most cases the results in the F_2 are what would be expected if it be assumed that the hybrids produce only the eggs of their mothers and only the sperms of their fathers. There are several rather striking exceptions to the last proposition, but the exceptions occur with a degree of consistency that promises to make possible some rather simple interpretation.

When *lamarckiana* enters into the hybrid combination the situation becomes extremely complex. At many points the same principle which works out with precision among the pure *cruciata* crosses can be detected with greater or less clearness, but in most cases it is obscured or completely hidden or destroyed by the more independent movement of characteristics of *lamarckiana*, including the broad petals, long style, redness of the bud-cones, and various features of foliage and habit of branching, all of which may be recombined in various ways with the cluster of egg-borne or sperm-borne characters of any biotype of *cruciata* with which *lamarckiana* may be crossed. These independent characters of *lamarckiana* do not readily take a Mendelian interpretation, however, the same character being in one combination dominant, in the other recessive, and almost never approximating an expected ratio, except perhaps 1 : 1 in several cases. Broad and narrow petals not infrequently occur on the different branches of the same plant.

Heredity in Butterflies, by John H. Gerould.

Professor John H. Gerould has been cooperating, as non-resident collaborator, in researches on heredity in butterflies. He makes the following report:

My principal work with butterflies this season has been with *Colias eurytheme*, in which I have studied the inheritance of albinism; I have material for the study of other color varieties, as *keewaydin* and *ariadne;* and I have again crossed this species with *C. philodice*. I have mated the species-hybrids together and with individuals of the original species, and have secured a few layings of fertile eggs from these matings. I expect this fall to raise butterflies from these eggs, or to bring them into the pupal stage before I put the stock entirely into winter quarters. The albino female of *C. eurytheme*, as in *C. philodice*, is a color-hybrid, a Mendelian heterozygote for color. Thus, from two *white* females of *eurytheme* received from Arizona early in June 1913, I raised family *a*, containing 29 white females, 24 orange-yellow females, and 57 males + 1 gynandromorphic male; *b*, containing 27 white females, 20 orange-yellow females, and 49 males.

One-half of the sons of a white female are presumably heterozygous for color, though yellow; so I have attempted to determine the proportions derived by mating white (heterozygous) females with *heterozygous* yellow males, whether 3 white females to 1 orange female, or 2 white females to 1 yellow female, as my experiments on *C. philodice* seemed to indicate; but my broods of this generation that have just been emerging do not settle the question. The families from white females mated to their own brothers (or other sons of white females) in which an excess of white female offspring appeared were small. In one such, *e* (from a^{59}, white female $\times$ a^{27} male), 9 white females and no orange females (+15 males) have thus far appeared. Possibly a^{27} male was a heterozygote for white, *y* (*w*), though, of course, yellow. In family *m* (*ex* b^{53} white female $\times$ b^{48} male, *i. e.*, son and daughter of a wild white female from Arizona) there are 38 males, 16 white females, 11 orange-yellow females; b^{48} male, the father, was presumably pure orange-yellow, not carrying the white latent.

The mother of this brood (b^{53} female) could not roll up her tongue. Of her 65 offspring about one-half are normal, one-half can not roll up the tongue, *i. e.*, 28 normal, 37 uncoiled. In the males the equal ratio obtains: 18 normal, 20 uncoiled; in the orange females, 5 normal, 6 uncoiled; in the white females, however, 5 normal, 11 uncoiled. These numbers indicate on the whole a regular heterozygous condition as regards abnormality of tongue.

Two white *eurytheme* females (a^{94} female and b^{78} female) were crossed with *philodice* male, which bears no orange (pale sulphur yellow). This family, *o*, is as follows: males 72, females 71 (white 36, orange yellow 35). The hybrids are somewhat intermediate in color between the two species, showing dominance of orange, though the orange suffusion upon the yellow background is reduced in extent in the hybrid. The other family, *p*, consists of 11 males, 7 females (4 white, 3 orange-yellow).

The white species-hybrids are almost or quite indistinguishable from the albinic *C. eurytheme*, but I have not yet studied them in detail.

The male gynandromorph that appeared in family *a* (a^{81}) is the son of a white female × wild male. The 57 other males of this family and 53 females are normal. Three wings of this individual bear the male color-pattern, but the right anterior wing has the color-pattern of the female (wide, spotted marginal band) with a ground-color of orange and of white in a mosaic, thus showing the influence of *both* of the female color varieties. The male external genitalia are perfect, but crowded to the left side of the median plane. The testis was well developed. No ovaries were found, but there is an imperfect development of the female external genitalia on the right of the posterior end of the abdomen.

I had obtained in 1912 (October to December) almost exclusively females from the cross between *eurytheme* female × *philodice* male—20 females, 2 males. Repeating this work shows (family *o*) exact equality between the sexes (72 males, 71 females). However, in the hybrid broods of 1913 the usual precocity of the male is seen to be upset by the crossing of the two species; 7 out of the first 9 to emerge (first two days of emergence) were males. I have thought that this upsetting of the usual precocity of the males may be connected with the apparent partial sterility of the species-hybrids. The females, after mating with male species-hybrids, have in many cases not shown an inclination to lay, though they are invariably full of mature eggs. The males may be in some cases sterile. I am still studying this matter.

I raised a brood of pure *eurytheme* from a wild female; it consisted of 214 males, 206 orange-yellow females. Many pupæ of this brood were iced, and I tried to mate the resulting adults, but without success, to determine what effect cold might have upon the germ-plasm. There were few males that emerged from the iced pupæ, 15 pupæ having been killed by the conditions in the refrigerator (excessive cold and perhaps dryness). I shall try this again. This large family ought to throw some light on the matter of variation within the species, since it contains examples of varieties *ariadne* (pale orange) and *keewaydin* (deep orange) regarded by some entomologists as seasonal variations.

I want to extend my experiments eventually by breeding *C. edusa* and *hyale* from Europe and the American species, especially *C. interior* of Canada, the nearest species to *C. philodice* and *eurytheme* geographically. *C. interior* has not been bred, and its food plant is said to be unknown, though I should be surprised if it would not lay on white clover. Species of the genus *Colias*, although very susceptible to disease and hence difficult to raise, are full of interesting possibilities in the study of the origin of species and heredity.

Inbreeding and Degeneration of Rats, by G. C. Bassett.

Dr. G. C. Bassett, who has been working, under the direction of Professor John B. Watson, at Johns Hopkins University, upon the consequences of inbreeding on the intelligence of rats, is temporarily attached to this Station and continuing his work here. His early investigation showed that after four generations of closest inbreeding (brother and sister within the litter) there was a loss in brain weight of from 7 to 10 per cent on the average and a loss in ability to form habits of about 30 per cent on the average; but no further important degeneration of the stock occurred, even to the tenth generation of inbreeding. Dr. Bassett's conclusion that on the average inbreeding is accompanied by deleterious effects upon the brain and intelligence accords with results obtained at this Station on the deterioration in the yield of maize upon self-pollination. Dr. Bassett proposes now to establish in the white rat a condition analogous to that of imbecility in man; to produce through inbreeding and selection a strain of rats of inferior intelligence, and to use this, in hybridization experiments, to test the inheritance of such mental inferiority. He proposes to study, at the same time, the effects of chronic parental alcoholism upon the progeny. This will comprise a study of brain and cord weight, blood and kidneys, and the intelligence.

The foregoing experiments are closely related to those begun at Goose Island by the Wistar Institute. Those experiments were discontinued by the Wistar Institute, as the evidence showed, first, that the albino rats could not survive alongside of the brown rats of the island, and, second, that the mere trapping of brown rats on Goose Island may not exterminate them, as there is evidence that the island is subject to invasion by rats from larger islands and those nearer the mainland. In the early spring (April) rats are absent or rare, but they have been trapped in large numbers during June every year since we have had the island.

Studies in Human Heredity, by C. B. Davenport.

That part of the Director's studies relating to the results of experiments in heredity that man is making on himself is comprised under the name Eugenics Record Office. This aspect of the work has received continued generous support from Mrs. E. H. Harriman and Mr. John D. Rockefeller. Its board of scientific directors includes Alexander Graham Bell, William H. Welch, Lewellys F. Barker, Irving Fisher, E. E. Southard, and C. B. Davenport.

The principal investigations now being conducted are: (1) the consequences of human inbreeding in an island population; (2) the consequences upon the physical and mental traits of a blood line, formerly highly inbred and very neurotic, but which for a generation

has been widely scattered, necessitating outbreeding; (3) the establishment of a norm, or control, by the complete study of a small New England township; (4) the inheritance of chronic chorea; (5) the inheritable basis of pellagra; (6) the inheritance of hare-lip in man and animals; (7) the continued study of the families of institutional cases of the insane, feeble-minded, and emotionally uncontrolled.

The Director has studied all available cases of close inbreeding and their progeny. While the product of the interbreeding of members of the same fraternity is usually neuropathic, it is hard to deny that this is due to the neuropathic condition of parents whose emotions are so uninhibitable. The progeny of mating between more remote relatives (cousins) frequently show no deterioration. These studies form the basis for a criticism of the numerous State laws limiting marriage selection.

The study has been made of strains to which belong a number of cases of eroticism and hysterical temper. Both traits appear clearly as Mendelian dominants. In this respect they are like chronic chorea, a condition characterized by uncoordinated movements apparently due to an inability to inhibit muscular contractions. Extensive data secured by one of the field workers of the Eugenics Record Office enable us to trace back the more prominent lines carrying chronic chorea to about six immigrants to North America over 250 years ago.

The inheritable basis of so many elements of behavior having been demonstrated, it seemed desirable to call attention in a popular article (Popular Science Monthly, July 1913) to the consequences of the fact, in the hope that unnecessary suffering and abuse, through a wrong interpretation of their behavior, might be saved to those whose reactions are atypical.

ISOLATION OF BIOTYPES, AND SELECTION.

Results of Selection of Color Pattern in Rats, by W. E. Castle and J. C. Phillips.

The work of the animal or plant breeder who seeks to create improved stock is largely done by selecting as breeders those individuals that reveal most nearly those characters that he is looking for. But since inheritance is from the germ-cells and since the soma gives only an inadequate and partial indication of the potentialities of the germ-cells, it is clear that selection on the basis of breeding capacity must ever be a better method than selection of the appearance, composition, or behavior of the soma of the individual. Historically it appears that progress has, nevertheless, been made by pure somatic selection; and it is important to know the details and results of this method. Our associate, Professor W. E. Castle, has just completed, in collaboration with Dr. John C. Phillips, and

turned in for publication a study of a somatic selection of the color pattern of rats, extending over seven years, in the course of which over 20,000 rats were raised and studied. The results, they believe, demonstrate the efficacy of mass selection; and they are led to conclude that selection is, in animal breeding, a more important agent than mutation, partly because it is controllable and its results therefore more certain, and partly because it may even determine the occurrence of mutations of a particular sort.

Quantitative Studies of Selective Elimination, by J. A. Harris.

During the year, Dr. Harris's studies on natural selection have been carried forward along the lines laid down in previous reports.

The results already published for differential mortality with respect to seed weight in field cultures of *Phaseolus vulgaris* have been fully confirmed and somewhat extended by planting about 46,000 individually weighed seeds in the green-house. There is unquestionably a reduction in variability in weight due to differential mortality. The data also seem to show that in some strains the higher mortality falls upon the heavier and in other strains upon the lighter seeds.

The results for *Phaseolus* have been confirmed on an extensive though smaller scale by field experiments on *Pisum*. Some progress has been made in the physiological phases of these investigations in that a correlation between weight of seed and time required for germination has been demonstrated in *Phaseolus*.

The selective elimination studies for seedling variants in *Phaseolus* have been continued on about double the scale and in greater detail than last year. The results can not be announced until the data are secured from the crops still in the field.

The studies of fertility and fecundity instituted to check the findings for the differential mortality of ovaries have been carried forward and in part published. So far as completed they confirm the results announced in Year Book No. 9.

Thus it was demonstrated in papers published from the Station in 1910 that the chances of development to maturity of the ovaries formed by a plant are conditioned upon the structure of these ovaries. It was proved, for example, that ovaries of *Staphylea* have a death-rate roughly proportioned to the number of carpels which are bilaterally asymmetrical with respect to the arrangement of their ovules. During the year results have been published showing that in *Phaseolus* such bilaterally asymmetrical ovaries are not only less capable of maturing their seeds, but that the seeds which they do produce are lighter than those borne in symmetrical ovaries. Thus the selective elimination and the physiological studies fully check and supplement each other. The information gained from them is now furnishing the basis for the study of asymmetry in the individual.

PURE LINES.

Influence of Weight of Seed upon the Character of Plants Produced, by J. A. Harris.

The question of the relationship between the weight of the seed planted and the characteristics of the plant produced—a problem which has necessarily been taken up at this Station because of its bearing upon questions of pure-line inheritance—is one of considerable practical importance. Extensive studies have shown that in *Phaseolus* there is regularly a positive correlation between weight of seed planted and number of pods per plant—yield increasing with weight of seed planted. But the correlation for weight and character of pods, that is, number of ovules formed and number of seeds matured, is much lower and is reduced practically to zero when correction for number of pods is made. Thus the yield in number of pods but apparently not the character of the pods produced is directly influenced by weight of seed planted.

Selection within the Pure Line, by J. A. Harris.

The studies on pure-line inheritance for seed weight have been continued, but publication has been delayed because of the many difficulties of analysis introduced by various physiological correlations. The number and magnitude of these difficulties has never been fully enough taken into account by those who have written on these questions. For example, the work at this Station has shown that there is a sensible correlation between the weight of the seed and the number of pods produced by the plant. There is also a correlation between the number of pods on the plant and the weight of the seeds which it produces. As a resultant of these correlations some relationship must be expected between the weight of the parent and offspring seed in the population. Again, our experiments on differential mortality with respect to seed weight show that physiologically considered this character is by no means a simple one. To distinguish relationships between parental and offspring seeds which are purely physiological from those which are genetic is a problem requiring further experimentation.

Selection for seedling abnormalities was begun in 1912 and carried out on a larger scale this year. It is too early to report results, although it may be noted in passing that some abnormal parents threw all abnormal offspring this year.

CLONAL.

Heredity in Parthenogenetic and Clonal Reproduction.

While the term "pure line" is strictly applicable only to self-fertilizing species, it is reasonable to expect that parthenogenetic and non-sexually reproducing species shall follow the same laws of heredity; and several studies have been made here with such species.

Dr. A. M. Banta has, as stated in the last report, selected inside of one "pure-line" of daphnids the most and the least sensitive to light. The species reproduces parthenogenetically. The data, including the reaction times of over 10,000 individuals, covering in some cases 50 generations, are now being reduced.

The Director, working with Miss Annie P. Henchman, studied the variation in the statoblasts of the fresh-water bryozoan *Pectinatella magnifica.* These seed-like buds carry marginal hooks whose number varies from 11 to 26. By budding, compound individuals or colonies are produced, each of which may contain from 100 to 900 statoblasts. All of the statoblasts of one colony are produced from the same germ-substance without a sexual process to complicate matters. There is a great range of variation inside of any one colony; *i. e.,* one colony has a mode at 15 hooks, but there are a few statoblasts with as few as 12 hooks and some with as many as 20. But when we compare colonies that are probably or certainly unrelated the mode and the range in the number of hooks are both quite different. Thus, in another colony, the mode is at 18 hooks and the range is from 15 to 22. Thus variation inside the non-sexually produced colony is less than the variation between colonies. As yet attempts at breeding from given statoblasts have not succeeded.

METHODS.

Statistical Analysis of Data.

Dr. J. A. Harris has given much time to improving statistical methods and has prepared a memoir on the calculation of inter-class and intra-class coefficients of correlation from class moments when the number of possible combinations is large.

The Director has published a third edition, slightly revised from the second, of "Statistical methods with special reference to biological variation."

Critique of Variation due to Heterogeneity of the Substratum, by J. A. Harris.

Dr. J. A. Harris had his attention called to the failure of one series of plantings of beans to give results in harmony with his conclusion that the larger the seed planted the greater the mean number of pods per plant. The series in question gave precisely opposite results. A study of conditions of the planting shows that the seeds of each weight-group had been planted in order across a garden plot that was selected for its apparent uniformity of soil yet there was a demonstrable loss of productiveness from one side of the row to the other, and the larger seeds were planted at the least fertile end. So great was the heterogeneity that the larger seeds actually produced fewer pods than the smaller. In statistical studies on relative productiveness, homogeneity of substratum is clearly of primary importance.

Methods of Rearing Chicks.

In rearing chicks we have until recently suffered from a mortality of over 75 per cent. By applying the methods worked out at the Storrs Agricultural Station for reducing white diarrhea (namely, by keeping chicks in the incubator three days after hatching) mortality from white diarrhea has been reduced to about 5 per cent. We still had a large number of deaths at about 4 up to 8 weeks, apparently from coccidiosis. By increasing the area of range per chick the density of the infection of the ground is diminished and the death-rate vastly decreased. Dr. H. D. Goodale employed this method here in 1912 and has continued its use at Amherst in 1913, with good results.

STATISTICAL SUMMARY.

Poultry.—Of chicks, 655 were hatched.

Finches.—Of canaries, 76 were hatched; 28 survived infancy.

Sheep.—Twenty-six sheep were born.

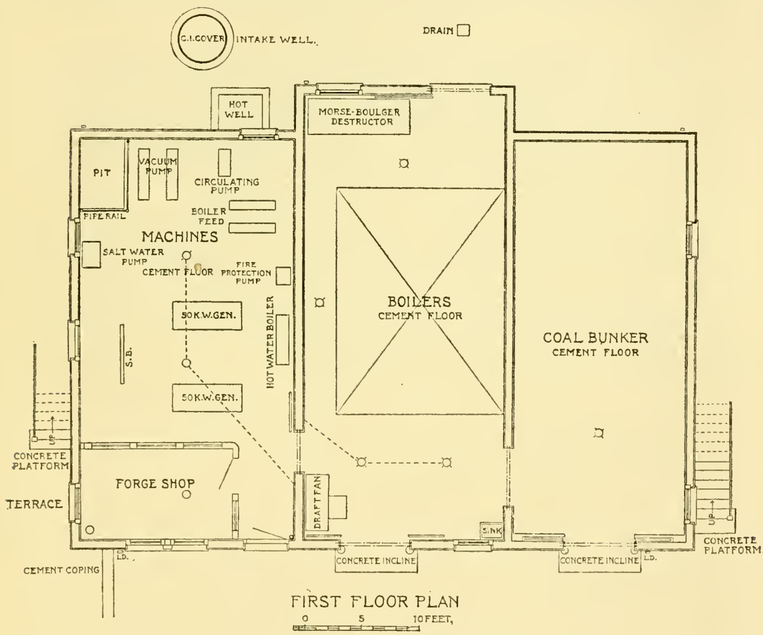
Plants.—No estimate has been made of the many thousand plants examined by Dr. Harris. The number and extent of cultures grown in connection with Dr. Shull's investigations are indicated by the accompanying table.

Name of species.	No. of families.	No. of individuals.
Bursa bursa-pastoris	13	2,200
Bursa bursa-pastoris×heegeri hybrids, F_2	4	1,099
Bursa bursa-pastoris×heegeri hybrids, F_3	7	1,987
Bursa bursa-pastoris×heegeri hybrids, F_4	12	3,696
Bursa bursa-pastoris×heegeri hybrids, F_5	58	16,482
Lychnis dioica	142	11,847
Lychnis dioica×coronaria	1	15
Oenothera cruciata	3	544
Oenothera gigas	1	74
Oenothera lamarckiana	17	944
Oenothera grandiflora	2	382
Oenothera nanella	1	78
Oenothera rubricalyx	1	119
Oenothera rubrinervis	10	2,404
Oenothera scintillans	1	20
Oenothera tracyi	1	156
Oenothera sp	1	13
Oenothera cruciata-lamarckiana hybrids	145	15,348
Oenothera cruciata-rubrinervis hybrids	6	711
Oenothera lamarckiana-rubricalyx hybrids	2	240
Oenothera lamarckiana-rubrinervis hybrids	2	80
Oenothera nanella×lamarckiana	1	44
Oenothera nanella×rubrinervis	1	45
Oenothera rubricalyx-rubrinervis hybrids	2	357
Total	434	58,885

CONSTRUCTION AND EQUIPMENT.

POWER-HOUSE.

To simplify the work of heating the buildings, including the greenhouses and bird-house, it was decided to erect a power-house near the harbor. This building, of hollow tile and concrete, is 55 by 37 (or 41) feet. It comprises a boiler-room, a room for machines, including space for a pair of future 50 k. w. electric generators, a small forge shop 8 by 13.5 feet, a coal bunker, a carpenter shop, and two rooms for workmen. It is expected to install one electric generator in 1914.



Power House.

ANIMAL HOUSE.

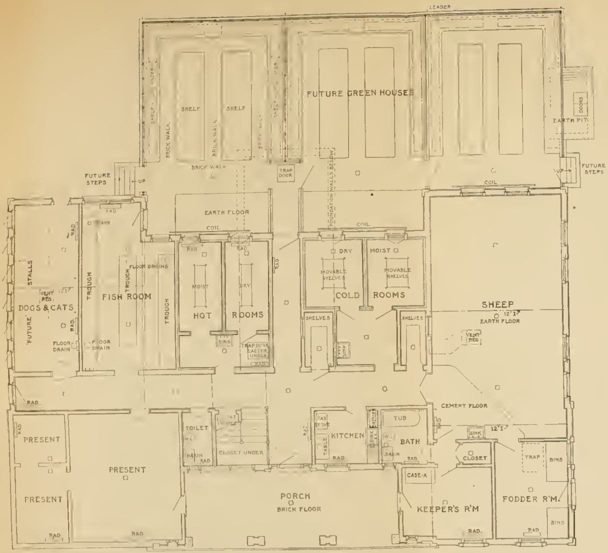
To relieve the crowded condition of the main building, to free it from the dirt incident to caring for animals in it, and also to remove the chemical laboratory to safe quarters, the Trustees provided for building a new "animal house." The building is 80 feet long by 50 feet wide; it is of hollow-tile construction covered with stucco. The roof is flat and of the Barrett specification type. The floors are of reinforced concrete with terazzo surface. The stairs are of steel

with slate treads. The first floor comprises four rooms for small mammals and one for sheep; also two suites of rooms whose walls are all insulated with cork, to be used for heat and cold experiments. This floor also has a room for aquatic animals, a kitchen for preparing food and sterilizing small dishes, and a small suite of rooms for an animal caretaker. The second floor comprises the chemical laboratory, 24 by 20 feet, with a weighing-room; a bird-room, 30 by 20 feet; a suite for operating, an adjacent hospital and laboratory, all together 40 by 18 feet; two laboratories, each 18 by 19 feet; a museum room, 14 by 11 feet; a dark room 22 by 8 feet; a fire-proof vault for records.

MISCELLANEOUS.

Our frame carpenter shop and the lumber shed were moved from their old sites to make room for the power-house, and set against the side hill. A retaining wall about 80 feet long and 6 feet high was built against the face of the slope. The excavated material was deposited upon the salt marsh and a full half acre has been thus reclaimed, which will be added to the garden.

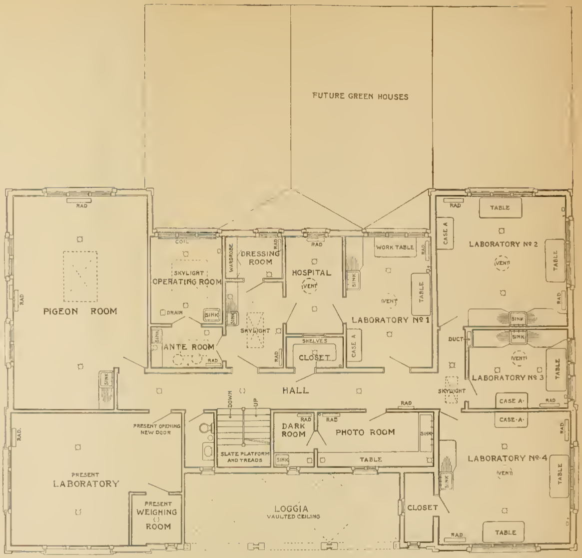
A water tower 50 feet high and a tank of 10,000 gallons capacity were installed and pipes laid to and from them. Two hydrants were placed and provided with hose. A stream of water can be thrown to the ridge of the laboratory and the animal house. The tank is kept filled by the ram at an expense of less than $10 a year, including new rubber valves and labor in replacing them.



FIRST FLOOR PLAN

0 5 10 FEET

Animal House, Cold Spring Harbor.



SECOND FLOOR PLAN

0 5 10 FEET

Animal House, Cold Spring Harbor.

GEOPHYSICAL LABORATORY.*

ARTHUR L. DAY, DIRECTOR.

In the annual report of a year ago some account was given of recent progress toward the attainment of a system of apparatus and of experimental technique for the simultaneous application of high pressure and high temperature in the study of mineral formation. This year it is possible to offer the first results of these studies.

MINERAL FORMATIONS UNDER PRESSURE.

It should perhaps be explained that the study of mineral formation under pressure implies somewhat more than may be immediately apparent from this brief statement. The effect of a uniform pressure greater than the prevailing pressure of the atmosphere upon the chemical and chemico-physical relations of solid bodies is very small, so small in comparison with the effect of a change of temperature that it may be accounted practically negligible unless the pressure change is very large. The effect of a uniform pressure of 1,000 atmospheres, for example, on the melting-temperature of a metal is (usually) to raise it 5° or 6°, while the greatest effect yet observed with any substance is less than 40°. If the effect on the minerals be of the same order of magnitude, as in all probability it is, then 1,000 atmospheres of pressure, which corresponds roughly to the weight of overlying rock at a depth of 2 miles, would cause a change in the melting-temperature of the minerals of the order of 1 per cent of its value—a factor which might fairly be neglected in considering the conditions of rock formation.

The foregoing remarks apply to pressure which is uniform, but the question assumes a different aspect if the compression is different in different directions. Such non-uniform compression, which certainly occurs locally at many points of the earth's crust, causes in general a lowering of melting-point and by an amount many times greater than in the simple case of uniform pressure. Such pressure may conceivably lower the melting-temperatures by several hundred degrees and become a factor of great geologic importance.

If we consider further that a mass of liquid rock (magma) has but small solubility for gases at atmospheric pressure, and bear in mind that substantially all the rocks in nature are found to contain gases and volatile matter in considerable quantity, then we shall see that high uniform pressure has also been influential in the progress of

*Situated in Washington, D. C. Grant No. 744. $78,000 for investigations and maintenance during 1913. (For previous reports see Year Books Nos. 3–11).

rock formation, but rather during the period before the solidification of the magma than after and rather in the sense of preventing the escape of gases and volatile matter which otherwise would have had little or no part in the solidification process. Thus we see that pressure has had most important effects, (1) in determining the composition of rocks by assuring the presence and chemical activity of the gases and volatile ingredients which otherwise might have escaped, and (2) throughout all dynamic activity in which considerable pressure differences are set up in the solid portions of the crust.

To reach a proper conclusion about the manner of mineral and rock formation upon the earth, it is therefore necessary to consider pressure and temperature conjointly in appropriate magnitudes, as well as to pay due attention to the character of the compression, whether uniform or otherwise. If we choose, as indeed it has been our habit to do, to study the formation of minerals under high temperature alone (crystallization from "dry" melts), this is merely a provisional expedient in the interest of simplicity; it enables us to distinguish the different active forces and to measure them separately instead of confronting the cumulative effect of a group of forces which we can not in the first instance analyze. We shall be much better equipped to attack the problem in its full complexity after its component factors have been separately studied.

There is no intention to intimate that studies of the joint action of high temperature and pressure are entirely novel. Indeed, the published work of the year—of which a summarized account may be found later in this report—is in part devoted to a detailed analysis of numerous papers bearing more or less directly upon this subject, and there are still other publications describing a variety of apparatus which is designed to find application in the prosecution of such studies. Nevertheless, there has been no study of mineral formation at high temperature and pressure under conditions such that the various factors which enter into such formation—pressure, temperature, the concentration of the ingredients, both volatile and other, the time of reaction, etc.—were all under control and accurately measurable. Indeed, it is nearly impossible to repeat any of the experiments hitherto described because of failure to control or to measure one or more of these essential factors, and for the same reason it is extremely difficult to draw valuable conclusions from the great body of that work. It is a situation of peculiarly anomalous character thus to stand at the threshold of a field of activity which has been cultivated at intervals for fifty years or more without being able to command any securely established vantage-point by gaining which the investigator might hope to accelerate his progress.

During the past year several attempts have been made in this Laboratory, partly by analysis and partly by experimental measure-

ment, to reach positive conclusions upon separate portions of this complicated problem.

First of all, the classical work of Spring and of his contemporaries, which covers the widest range of application of pressure (at ordinary temperature) to solid substances hitherto undertaken, and which has led to a number of contradictory conclusions, was examined with great care and portions of it were repeated in this Laboratory. It has proved to be possible to throw considerable light upon this confused situation. It was discovered, for example, that many of Spring's experiments were conducted in a bomb with a loose-fitting piston (witness the frequent squeezing out of his materials past the piston), while that of his contemporaries was carried out for the most part in bombs with tight-fitting pistons. The distinction is vital. After the first crushing together, the former method gives a non-uniform compression which produces deformation of the material, the latter a nearly uniform or hydrostatic pressure, with very little or no permanent deformation of the material. When viewed in the light of this distinction in the character of the compression (a distinction which appears to have passed unnoticed at the time), many of the contradictory conclusions which have cast a shadow over this great mass of experimental data are happily removed and definite and tangible results have taken their places.

Still further uncertainty was removed from the problem of the interpretation of those experiments which were offered in support of the contention that chemical reaction between solid salts is promoted by pressure. With uniform pressure the reaction takes place only at the surface of contact, and reaction velocity at ordinary temperatures is practically *nil*. With non-uniform pressure, which always produces deformation of the material, new surfaces are continually brought into contact and a greater total of surface reaction results, but the cases are in other respects identical. From this it follows that pressure, of itself, is without direct effect in producing chemical reaction in solid systems, nor does it affect appreciably the reaction velocity.

These studies have interest not alone to the geophysicist, for their value in helping to elucidate problems of earth formation, but also to the physicist as a contribution to our knowledge of the properties of matter. In fact, as a result of the investigation a tentative theory of general application has been offered of which the physicist may find frequent occasion to test the validity in future work in this domain. It is in effect that "every *permanent* deformation of a crystalline aggregate is conditioned by a real local melting of those particles which at any instant bear the brunt of the load."

In addition to the analysis of the effects of pressure upon crystalline aggregates, the study of systems, one component of which was

gaseous at those temperatures where the formation process is active, was initiated. Valuable results have already been obtained from work on systems with water or CO_2 as volatile ingredients in combination with certain of the common components of igneous rocks. The experiments are of rather limited scope thus far, and only the simplest combinations have been tried, but the results are definite and in full accord with existing physico-chemical theory as hitherto applied to aqueous solutions of salts at ordinary temperatures and comparatively low pressures. Three papers have thus far been published upon this subject, of which brief reviews will be found under numbers 19, 24, and 27. The laboratory technique of such studies at high temperatures and pressures is extraordinarily difficult, as has been explained in the annual report of this department for 1912, but the definite and concordant results thus far achieved furnish a more than sufficient reward for trouble already encountered and an adequate incentive for further effort in this domain, which is of paramount importance to our knowledge of rock formation in nature.

CALORIMETRY.

Recent progress in the study of the calorimetry of the minerals may be briefly summarized as follows:

(1) Some new calorimetric devices, already briefly described in print, have been installed and tested. They are intended especially for obtaining high precision in protracted determinations.

(2) The calorimetric platinum-wound furnace has again been studied, remodeled so as to diminish some accidental errors troublesome in previous work, and recalibrated.

(3) The specific heats have been partly determined for platinum, various forms of silica, and 15 silicates, some crystalline and some glassy, throughout the temperature interval from 300° to (in some cases) 1500°. This work, which is still in progress, shows accidental errors of a magnitude less than 0.0005 of the quantities measured. The agreement with the best previous work of this Laboratory is also entirely satisfactory.

Among the more general results already obtained are the following: The specific heat of platinum shows an *increase,* which to the full precision of the measurements, is *uniform* from 700° to 1300°. This seems likely to prove an important criterion of certain molecular theories which indicate that it ought not to increase in this way. There is a slight divergence from the linear law near 500°, which may not be characteristic of pure platinum, and is to be further examined.

Some of the silicate glasses show irregularities in the increase of the specific heat with temperature.

Melting and inversion are accompanied by specific heat variations which promise to shed light upon some recent theories as to these changes.

THE TEMPERATURE FACTOR IN THE OPTICAL STUDY OF CRYSTALS.

Two new pieces of accessory apparatus for use with standard instruments of petrographic research deserve more than passing notice. The first is a small furnace arranged to be mounted directly on the table of the petrographic microscope. It is completely inclosed by running water, so that no heat escapes to disturb the optical adjustments of the instrument. It differs from apparatus hitherto constructed for the optical study of crystals with changing temperature in that it provides for turning the crystal about an axis perpendicular to the line of sight during the observations. A graduated circle measures the amount of the rotation. The apparatus permits the accurate determination of three optical constants, the birefringence, extinction angle, and optic axial angle, of properly oriented crystal plates up to temperatures as high as 1200°. (Review No. 11 *seq.*)

The second apparatus has a similar purpose, namely, to equip the Goldschmidt two-circle goniometer with a similar water-inclosed furnace, through the use of which the interfacial angles of crystals, as well as their refractive indices (minimum deviation method), can be conveniently and accurately measured within the same temperature range. (Reviews Nos. 17 and 44 *seq.*)

All optical determinations through which crystalline minerals are classified and their properties defined are subject to variations of unknown magnitude with change of temperature. It will, therefore, be one of the important problems to be actively prosecuted during the coming winter to establish the magnitude of the variation with temperature of a number of these optical constants. These two furnaces together provide for the complete control of this variable and hitherto neglected factor in the optical study of all crystals. The temperature at which crystallographic and optical properties of minerals have a measured value is of the same importance and has the same significance as a knowledge of the temperature corresponding to a given value of the specific gravity or the specific heat. It is not proper to speak of these as characteristic constants except for a definite temperature.

VOLCANO STUDIES.

The further prosecution of the field studies at the Kilauea volcano, of which some account was given in Year Book No. 11, page 99, has been interrupted for the moment because of the cessation of the volcanic activity there. It is planned to resume the investigation as soon as a favorable opportunity offers. Meanwhile the laboratory study of the material, both lava and gases, gathered in 1912, is proceeding rapidly. The analysis of the gases shows them to be made up primarily of free sulphur, free hydrogen, CO_2, SO_2, CO, H_2O, and N_2, the proportions varying with each bubble which bursts through the liquid lava.

It is obvious from a glance at this group of gases that they can not exist together at a temperature of 1000° or more without inter-reaction, and that the reactions are of a kind to produce heat in considerable quantity. Reaction will begin between the gases in the rising lava column the moment pressure has diminished to the point where they begin to be released from solution. As the lava rises to the surface, the pressure upon it diminishes steadily, setting free a continually increasing quantity of gas which is then free to enter into new chemical relations. This chemical activity will be a maximum at the surface at the moment of discharge into the atmosphere.

It would seem to be a necessary consequence of this mode of release of the gases previously in solution and the resulting exothermic reactions between the gases after release, that the temperature of the lava lake should rise when the quantity of gas given off is large, and should diminish again when the gaseous exhalation diminishes in volume, and this was found to hold true throughout the activity of the summer of 1912, of which we were witnesses. The measured changes of temperature in the lava in this interval of about four months (the quantity of lava in the basin remaining practically constant) amounted in maximum to 115°. This represents a total quantity of energy of very large magnitude which has not been reckoned with hitherto in the consideration of the problem of volcanism.

The much mooted question whether water is an active participant in volcanic activity appears to be answered conclusively in the affirmative so far as Kilauea is concerned. Not only was water actually collected in considerable quantity (300 c.c.) directly from the liquid lava at a temperature of 1000°, but this was done under conditions which completely excluded contamination with air. Moreover, the presence of free hydrogen associated with CO_2 and SO_2 at this temperature is of itself a sufficient guarantee of the presence of water among the volcanic gases. Indeed, the reaction between H_2 and CO_2 (the water-gas reaction, $H_2+CO_2 \rightleftarrows CO + H_2O$) has long been well known and has been studied in great detail.

It is of considerable importance to note further that the nitrogen exhaled by the volcano contains no argon. Bearing in mind that argon is always present in the atmosphere in measurable quantities, and that it enters into no chemical combination whatever, it would seem to be a necessary conclusion that the atmosphere does not contribute to the gases given off by the lava. If atmospheric ingredients were present in the lava, then surely the argon must be given off again. This must apply to all atmospheric ingredients, including water, whether originally gaseous or condensed; for if meteoric water were to find its way into the lava it must do so as a gas and

on the same terms as the other atmospheric gases, for the reason that the critical temperature of water is but 374° and the effect of the salts which might chance to be in solution in it will hardly prove adequate to raise this temperature to the order of magnitude of the lava temperature (1000° or more).

It is also of interest to note that the exhalation contains but a trace of chlorine (about one part in a thousand).

THE SECONDARY ENRICHMENT OF COPPER SULPHIDE ORES.

To be both broad and thorough the investigation of such a problem as the secondary enrichment of copper sulphide ores must be undertaken partly in the field and partly in the laboratory, and it will involve the application of a number of different sciences. The actual processes of deposition, however, are unquestionably chemical and will fall to the share of the laboratory for elucidation.

The general direction which such a chemical investigation should take is clear, though the path may be difficult. The plain task of the chemist is to test the natural conditions supposed to have been active in the deposition of the ore, or in a word to reproduce the results of nature in the laboratory and under conditions which can be carefully controlled and measured—and these conditions, it should be added, must include the conditions either known or supposed to have existed during the deposition in nature. It is not sufficient merely to reproduce the results.

Not only must the conditions which attend such deposition be known and measurable, but a chemical investigation like this also demands a considerable body of precise information about the minerals involved. Now, the majority of these minerals have never been regarded as definite chemical substances. An examination of the chemical text-books, even the fullest, reveals but a meager and unsystematic knowledge of them and that which has been recorded is commonly relegated to the fine print. Such chemical tests as have been made were undertaken by mineralogists, generally for purposes of identification.

A systematic knowledge of the mineral sulphides does not exist. We must learn the individual composition of these substances, whether it is fixed or variable; and, if variable, within what limits. We shall require a systematic knowledge of their chemical reactions one with another, such as we have of the more common compounds of everyday laboratory experience. The temperature range within which these substances can have a stable existence must be known, whence thermal studies are indispensable. A knowledge of their dissociation pressures would be of great practical value, both to chemistry and to geology, and an investigation of these ought to be begun in the not distant future. Methods of separation and identification of the sulphides

are much needed for the synthetic work, and, although the field of possibilities must remain somewhat restricted here, when compared with more soluble substances, nevertheless the sulphides possess considerable advantage over the silicates in this particular. Finally, for a reasonably complete knowledge of the sulphides the redetermination of such physical constants as the specific gravity and crystal angles on pure synthetic or exceptionally fine natural material is much needed.

The direct investigation of secondary sulphide enrichment; *i. e.*, the precipitation of heavy metals from solution by various sulphides, has hitherto been confined chiefly to qualitative tests. In the light of a fuller physical and chemical knowledge of the mineral sulphides, these processes should now be studied quantitatively.

A strange notion prevails that in work of this character the important thing is to imitate nature's complexity. Even very recent numbers of scientific journals contain work in which this principle is still followed. The exact opposite is of course the practicable method. The action of the simple and pure sulphides must first be tried separately with each of the principal constituents which are found in the natural solutions.

There is also a tendency among students in this field to confine themselves strictly to natural conditions, even in respect to temperature and time. This is obviously quite impracticable also, except perhaps for those favored amateurs who are not subject to the usual limitations of time and economic considerations. A more successful and much more expeditious plan is to raise the temperature to a point where the reaction to be studied attains a measurable rate, and having ascertained its nature, to find how it is affected by changes of temperature.

In the study of these reactions with the sulphides, mixtures are often obtained which are quite difficult to deal with. It is then of the first importance to find what and how much goes into solution and what and how much is precipitated. It is perhaps too much to expect that *all* the alterations which the sulphides of copper appear to undergo in nature during the processes of secondary enrichment can be duplicated in the laboratory within a limited time, but active work is now in progress all along the line, and enough has been accomplished already to assure a good measure of success.

One feature of this undertaking is novel. It is one of the very few instances where geologists in the field have cooperated directly with physical-chemists in the laboratory on a geologic problem. To the chemist the opportunity to get material and data from a wide area and to have chemical predictions tested by field observations is quite unusual, and the possibility of mutual suggestion between the field and the laboratory worker is full of promise.

PUBLICATIONS.

Brief reviews of the papers published by members of the laboratory staff during the current year follow, together with synopses of some that will appear at an early date:

(1) Oblique illumination in petrographic microscope work. Fred. Eugene Wright. Am. Jour. Sci. (4), 35, 63–82. 1913.

The study of interference phenomena resulting from oblique illumination between crossed nicols enables the observer to determine many optical features in a given mineral plate. These phenomena are identical, so far as interference colors go, with the phenomena obtained in interference figures from the same plate in convergent polarized light. The study of mineral plates by the method of oblique illumination is of value because it impresses the mind of the observer with the interdependence of optical and crystallographic properties. It is, however, highly important that the observer realize the essential agreement between the phenomena observed in oblique illumination and those seen on interference figures in convergent polarized light. In the interference figures the interference color phenomena are seen at a glance, and if they be studied with reference to the position of the mineral from which they are obtained, all of the conclusions to be ascertained by means of the method of oblique illumination can also be derived with even greater facility from the interference figure. For the study of interference phenomena the method of oblique illumination does not offer any special advantages over the convergent polarized light method, but it does present certain disadvantages in manipulation and in the distinctness of the phenomena observed which can not be disregarded entirely. This is especially true if oblique illumination be obtained by use of a stop in the eye-circle of the ocular, as recently suggested by Schneiderhöhn.

In this paper the phenomena produced by oblique illumination have been discussed in some detail. Attention should also be directed to an obvious but important fact, too often disregarded in petrographic microscope work, that for the accurate measurement of extinction angles, central illumination by parallel plane-polarized light is highly essential. Satisfactory measurements of extinction angles can not be made when the section is illuminated by a strongly convergent cone of light, incident under all angles and in all azimuths.

(2) An improved vertical-illuminator. Fred. Eugene Wright. J. Wash. Acad. Sci., 3, 14–16. 1913.

Of the two types of vertical-illuminators which are in current use on the metallographic microscope, the reflecting-prism type furnishes the best illumination with low-power objectives. With high-power objectives it is less satisfactory, because the reflecting prism cuts off half of the rays from the objective and thus seriously impairs the resolving power and general efficiency of the optical system. The second type of illumination with the Beck illuminator does not suffer from this defect, as the light which is reflected from the thin glass plate passes, on its return after reflection from the metal surface, through the glass plate itself on its way to the eye of the observer. The glass plate thus serves both to reflect and to transmit the light; the resulting intensity of illumination is, however, noticeably less than that obtained by the first method. For satisfactory work the glass plate should be plane and thin and the source of light so arranged that none of the rays reflected from the objective lens surfaces reach the eye of the observer; otherwise they cast a haze or fog over the entire field, thus reducing the contrasts and flooding the image with false light.

A device has been constructed in the Geophysical Laboratory to correct this defect and has been found satisfactory and useful in practice. It enables the observer to produce an aperture of any desired size in any part of the field; he has thus control over the entire field and can eliminate any incident rays which would otherwise disturb the kind of illumination desired. He can, moreover, obtain rays of any desired obliquity of incidence and thus increase or decrease the apparent relief of the surface under observation.

(3) Are quantitative physico-chemical studies of rocks practicable? Arthur L. Day. Compte Rendu, XI Congrès International Géologique Stockholm, vol. II, pp. 965–967. 1910.

An address before the Section on Mineralogy and Petrography of the Eleventh International Congress of Geologists, in which an effort was made to show by reference to recent laboratory studies of simple mineral relations, using physico-chemical methods, that these methods must eventually find application in the study of the very complicated mineral systems (the igneous rocks) also.

(4) Media of high refraction for refractive index determinations with the microscope; also a set of permanent standard media of lower refraction. H. E. Merwin. J. Wash. Acad. Sci., 3, 35–40. 1913.

A number of experimental studies have been carried on for the purpose of extending the conditions under which determinations of refractive index by means of the microscope can be made. Such determinations require immersion media of standard refractive index. Various immersion liquids have been in use for the determination of refractive indices over the interval 1.33 to 1.80; mixtures of amorphous sulphur and selenium have been found useful over the range (for sodium light) 2.1 to 2.4. The immersion media described have been devised to fill the gap 1.80 to 2.10, and to extend the series beyond 2.4_{Na}, or in special cases, particularly when a refractometer is not at hand for standardizing the liquids, take the place of media hitherto used. For the latter purpose solids have been found which may be mixed in given proportions by weight to produce permanent standard media.

(5) The index ellipsoid (optical indicatrix) in petrographic microscope work. Fred. Eugene Wright. Am. Jour. Sci. (4), 35, 133–138. 1913.

This paper emphasizes the importance of presenting the subject of microscopical petrography consistently from the viewpoint of the index ellipsoid as applied to wave-front normals. The various optical properties employed in practical petrographic microscope work can be best described and explained systematically by means of the index ellipsoid. The use of the so-called "axes of elasticity," $\mathfrak{a}$, $\mathfrak{b}$, $\mathfrak{c}$, or X, Y, Z, in this connection is confusing and only adds to the difficulties encountered by the observer in mastering the subject. They should accordingly be abandoned and the French usage of naming the principal axes of the index ellipsoid α, β, γ (or n_p, n_m, n_g) adopted. This applies in particular to the different modes now in vogue for expressing extinction angles. For a given crystal face an extinction angle is simply the angle between a definite crystallographic direction on the face and one of the axes, α' or γ', of its optic ellipse, and this fact should be indicated in the expression for the extinction angle. To introduce "axes of elasticity" ($\mathfrak{a}'$, $\mathfrak{c}'$, or X', Z') in this connection is not only needless, but less direct, as it introduces entirely new conceptions which experience has shown only tend to bewilder the student.

(6) On the effect of high pressures on the physical and chemical behavior of solids. John Johnston and L. H. Adams. Am. Jour. Sci. (4), 35, 205–253. 1913.

This paper is an endeavor to review and define the present status of our knowledge of the effect of high pressures on the behavior of solids, to reconcile some of the conflicting statements to be found in the literature pertaining to the subject, and to indicate the conclusions which may justifiably be drawn from the available evidence, especially with regard to their application to the discussion of geological phenomena. Some of this confusion results from the employment of indefensible criteria in ascertaining the character and magnitude of the change produced by pressure, as, for example, in determining the effect of pressure in promoting chemical reaction between solids; but in the main it is due to failure to take into account the fact that the effects produced depend upon the character, or mode of action, of the compression. The effects are different, namely, according as we are dealing with pressure uniform in all directions (true hydrostatic pressure) or with a mode of compression which does not satisfy this condition; in other words, the effects vary—as indeed is almost obvious—according as the solid retains its original form or undergoes deformation.

Uniform pressure has a comparatively slight effect on the melting-point; it usually raises it, and by an amount which, in the systems hitherto investigated, is seldom greater than 10°, and never greater than 40°, per 1,000 atmospheres. Its effect on solubility is slight, and for practical purposes negligible as compared with the influence of temperature upon solubility. Uniform pressure tends to further those reactions which are accompanied by a decrease of volume; but it by no means follows that it will cause these (or other) reactions to occur; for whether a reaction takes place or not is determined by its velocity under the particular conditions, and such evidence as there is tends to show that reaction velocity is not much affected by uniform pressure.

The effects of non-uniform pressure greatly outweigh those of uniform pressure. It *always* lowers the melting-point and raises the solubility, and by amounts which are many times greater than the corresponding changes with uniform pressure. Indeed, if we make the plausible assumption that permanent deformation of a crystalline aggregate is conditioned by a real local melting (of those parts which at any moment bear the brunt of the load), we find the amount of pressure required to cause melting at ordinary temperature to be well within the bounds of probability. Such we believe to be the efficient cause in producing most of the phenomena recorded as occurring when solid systems were submitted to compression. This view, while it coordinates satisfactorily the whole of the experimental work hitherto done, conflicts with none of the available direct evidence. It follows, therefore, that we can determine the effect of pressure on a solid system only if we can define the character of the compression (with reference to its approach to uniformity or otherwise) as well as its magnitude; and even then only when the requisite thermal and other data, characteristic of the system, are available.

(7) Über den Einfluss hoher Drucke auf das physikalische und chemische Verhalten fester Stoffe. John Johnston und L. H. Adams. Z. anorg. Chem. 80, 281–334. 1913.

A German translation of "On the effect of high pressures on the physical and chemical behavior of solids" (Am. Jour. Sci. (4) 35, 205–253, 1913). Reviewed under No. 6 above.

(8) La mesure des températures élevées par le thermomètre à gaz. Arthur L. Day and R. B. Sosman. Jour. d. Physique (5), 2, 727–749; 831–844; 899–911. 1912.

A translation into French, by Professor P. Chappuis, of "High temperature gas thermometry" (Carnegie Institution of Washington Publication No. 157, 1911). The material has been somewhat condensed and rearranged, and the later work on the revision of the lower portion of the high-temperature scale and on the boiling-point of sulphur ("The nitrogen thermometer scale from 300° to 630°, with a direct determination of the boiling-point of sulphur," Am. Jour. Sci. (4), 33, 517–533, 1912, reviewed in Year Book No. 11 (1912), p. 101) included.

(9) Two varieties of calciovolborthite (?) from Eastern Utah. W. F. Hillebrand and H. E. Merwin. Am. Jour. Sci. (4), 35, 441–445. 1913.

From chemical studies, two minerals from Paradox Valley, Colorado, are considered to be varieties of calciovolborthite. In the absence of optical data concerning the original mineral, the following optical properties, determined from one of these varieties, are assigned to calciovolborthite. Color, yellow-green, with no distinct pleochroism; biaxial, with strong inclined dispersion; optically negative for blue and positive for red; $\alpha = 2.01$, $\beta_{Na} = 2.05$, $\gamma_{Na} = 2.10$. The optical properties gave evidence of monoclinic symmetry.

(10) The determination of the order of agreement between observation and theory in mineral analyses. Fred. Eugene Wright and C. E. Van Orstrand. J. Wash. Acad. Sci., 3, 223–231. 1913.

Of the methods available for comparing the observed results of a mineral analysis with those obtained from the chemical formula to which the analysis corresponds approximately, the best method is to ascertain first the weight numbers (derived from the chemical formula by multiplying these ratios by the proper molecular weights), and then to adjust these values to the given analysis by the least-squares method. Since the computations involved are, however, somewhat laborious, and furthermore, since there is a limited number of observations and the systematic errors of observation are, in general, large as compared with the accidental errors, a simpler method is preferable for general use. The method proposed furnishes results which are very nearly correct and consists simply in reducing the weight numbers proportionately so that their sum is equal to that of the given analysis. In other words, we compare the actual analysis directly with the weight percentage analysis computed from the inferred chemical formula, both analyses having a common sum. The differences between the observed and computed values are then a sufficient measure of the degree of agreement of observation with theory.

(11) A new thermal microscope for the measurement of the optical constants of minerals at high temperatures. Fred. Eugene Wright. J. Wash. Acad. Sci., 3, 232–236. 1913.

With this microscope three optical constants—birefringence, extinction angle, optic axial angle—of a properly oriented crystal plate can be measured accurately at any temperature between 10° C. and 1200° C. Above 1200° the intensity of illumination from the furnace itself is so great that it tends to veil the optical phenomena produced by the polarized light-waves transmitted through the plate. The thermal microscope consists of two parts: (1) a petrographic microscope equipped with a suitable device for

simultaneous rotation of the nicols; (2) an electric resistance furnace completely inclosed within a cylindrical water-jacket and mounted upon the microscope table. The furnace differs from those which have been used hitherto in having an opening at the side through which passes a hollow shaft perpendicular to the axis of the furnace and optical system of the microscope. The shaft supports the crystal in the axis of the furnace and permits it to be rotated upon the horizontal axis as desired. A graduated circle on the shaft measures the rotation. The hollow core of the shaft carries the thermo-element with the junction in contact with the crystal and provides for temperature measurements when desired.

(12) The melting phenomena of the plagioclase feldspars. N. L. Bowen. Am. Jour. Sci. (4), 35, 577–599. 1913.

The method of quenching was applied to the determination of the melting intervals of pure, artificial plagioclase feldspars. It was found possible to determine accurately the temperatures of beginning of melting (solidus) for compositions ranging from pure An to Ab_3An_1, and of completion of melting (liquidus) for the range An to Ab_8An_1. Very pure natural material, Bakersville oligoclase, was used to determine the point on the solidus corresponding to its composition. Similar material, Amelia County albite, served to fix the melting-point of albite. The results of this work are summarized below.

Composition.	Temperature of beginning of melting. (Solidus.)	Temperature of completion of melting. (Liquidus.)
An	1550°±2°	1550°±2°
Ab_1An_5	1465°±4°	1521°±2°
Ab_1An_2	1372°±4°	1490°±2°
Ab_1An_1	1287°±4°	1450°±2°
Ab_2An_1	1205°±5°	1394°±2°
Ab_3An_1	1175°±8°	1362°±2°
$Ab_{77.5}An_{22.5}$	1158°±5°	....
Ab_4An_1	....	1334°±2°
Ab_8An_1	....	1265°±3°
$Ab_{98}An_2$	1100°±10°	....

It was also found possible in several instances to determine the composition of the liquid phase present at temperatures within the melting interval, by measuring the refractive index of the quenched glass. Thus points on the liquidus were determined by an independent method and were found to be in excellent agreement with the results of the temperature method.

In the theoretical discussion, equations are developed which express the concentrations on the liquidus and solidus at any temperature in terms of the melting temperatures and latent heats of melting of the two components. The experimental results, therefore, make possible the calculation of the latent heat of melting of anorthite and of albite. The calculated values are 104.2 calories per gram for anorthite and 48.5 calories per gram for albite, and these values remain practically constant for all ranges of composition. The calculated latent heat of anorthite is in excellent agreement with the figure found by direct measurement, 105 calories per gram. No direct determinations of the latent heat of albite have been made.

It is shown that if these values of the latent heats are taken and liquidus and solidus curves calculated, the resulting curves pass very close to the experimentally determined temperatures (within the limits of error of the

temperature measurements). It is also shown that values of the latent heats differing from these by as little as 10 per cent will not give a like result. This extreme agreement with the requirements of theory and its bearing on certain theoretical questions is discussed.

The geological significance of the complete solid solution of the feldspars is considered, as well as the extent to which zoning may occur under favorable conditions and the consequent very great range of temperature through which plagioclase may crystallize.

(13) Die Schmelzerscheinungen bei den Plagioklas-Feldspaten. N. L. Bowen. Z. anorg. Chem., 82, 283–307. 1913.

A German translation of "The melting phenomena of the plagioclase feldspars" (Am. Jour. Sci. (4), 35, 577–599, 1913). Reviewed under No. 12 above.

(14) New modified thermo-electric methods in calorimetry. Walter P. White. J. Wash. Acad. Sci., 3, 319–321. 1913.

In the common calorimetric method, the "method of mixtures," the work of the last five years has shown that the error due to heat-loss from the calorimeter into the air, once thought to be an unconquerable foe to accuracy, is ordinarily quite negligible. With a proper installation, the attainment of very high precision, to 0.1 per mille or better, requires merely sufficient precision in the temperature measurement. Such precision has been attained with the thermo-electric thermometer system, as has already been shown elsewhere. The present paper deals with the securing of certainty and high precision by means of the thermo-element. The essential feature of the methods is to use, around the "cold junction" of the thermo-element, in place of an ice-bath, a body at nearly the same temperature as the calorimeter. The smallness of the electrical quantity to be measured then gives to the temperature measurement extraordinary precision combined with extraordinary ease. These methods, accordingly, while specially advantageous for precision in determining very small heat quantities, are in nearly all cases among the best in convenience and certainty. A precision of 0.0001° is easily reached, under fair conditions, with a thermo-element of 24 couples. Elements of 8 couples, ordinarily precise to 0.0003°, are so very compact that the use of anything smaller will rarely be advisable.

(15) Note on the temperature in the deep boring at Findlay, Ohio. John Johnston. Am. Jour. Sci. (4), 36, 131–134. 1913.

A record of a series of temperature observations made in a hole drilled to a depth of 3,000 feet in the neighborhood of Findlay. The temperature gradient in the sedimentary rocks at horizons between 1,100 and 2,600 feet proved to be about 0.41° C. per 100 feet, which is smaller than what has been considered the common average value of this gradient.

(16) Data on the intrusion temperature of the Palisade diabase. R. B. Sosman and H. E. Merwin. J. Wash. Acad. Sci., 3, 389–395. 1913.

In the Palisade diabase of New York and New Jersey there frequently occur slabs of shale and arkose sandstone which seem to have been floated up into the diabase sheet while the latter was still liquid. A study was made of the comparative fusing temperatures of the diabase and the arkose. The lowest melting portion of the diabase begins to fuse at about 1150°, but only at 1225° is enough of the rock fused to permit it to flow readily. The arkose

is more than half fused at 1150°. Yet the inclusions as actually found show no indication of fusion or flow. The most probable explanation of this discrepancy is that the fusion temperature of the diabase has been lowered at the time of intrusion, by water or other volatile components which are no longer present in the rock.

(17) An electrical goniometer furnace for the measurement of crystal angles and of refractive indices at high temperatures. Fred. Eugene Wright. J. Wash. Acad. Sci., 3, 396–401. 1913.

In this furnace the effort has been made to produce an instrument of fair precision which may serve not only for the measurement of the interfacial angles of a crystal, but also for the direct measurement of its refractive indices at any temperature up to 1225° C., at which temperature the light of the furnace becomes relatively intense and the measurements are correspondingly less satisfactory.

The furnace fits as an attachment on the Goldschmidt two-circled goniometer. It consists of two flat disks of alundum (7 cm. in diameter and 5 mm. thick), on one side of which a spiral of 1.75 mm. pitch is stamped; into its grooves platinum wire 0.4 mm. thick is wound and then covered with a thin layer of alundum cement and baked at 1200° to 1300° C. These disks are backed by magnesia powder and mounted in hollow cylindrical water-jackets. Their edges are shielded from direct contact with the water-jackets by asbestos-wool packing. Since alundum is a good conductor of heat the alundum segments tend effectively to render the heat distribution uniform at the center of the furnace, while the outside asbestos rings are poor conductors and tend to confine the heat properly. Temperatures are read by means of the thermo-element in contact with the crystal, either on a millivoltmeter of the Siemens and Halske type or on one of the potentiometer-galvanometer systems of this laboratory.

After the proper electric and water-jacket connections have been made, the furnace can be carried to any temperature up to 1225° and the crystal angles or the refractive indices of a prism measured by the ordinary room-temperature methods. As the crystal is inclosed in the furnace a dark-room is not necessary for the measurements.

It may be of interest to note that recent preliminary measurements in the goniometer furnace on a cleavage rhomb of calcite indicate that the cleavage angle of calcite at 600° C. is 75° 52′, while at room-temperature (30°) it is 74° 55′, a change in the cleavage angle of nearly 1 degree during a temperature rise of about 600°. At 700° the calcite crystal faces lose their luster and become white (formation of CaO) and are valueless for goniometric work. The above change in cleavage angle indicates an average increase of 1 minute in angle for every 10° temperature rise. It would seem, therefore, that the practice of expressing crystal angles to seconds of arc without giving the temperature at the time of measurement can serve little purpose and is in fact illusory as regards the actual accuracy implied.

An extended series of measurements of the change of the optical properties and crystallographic angles of the rock-making minerals with temperature rise has been commenced at the Geophysical Laboratory.

(18) The volcanic cycles in Sardinia. H. S. Washington. Advance publications, XII Congrès Géologique International, Toronto, 1913.

The volcanoes of northwestern Sardinia were studied in the autumn of 1905 as part of a research under Grant No. 95. They belong to three

distinct periods, with interesting lavas, which show very marked cycles, or recurrent successions of characters, in their eruptions. These lavas are now being studied, and are soon to be described, along with some forty analyses.

Taking these volcanoes as a text, some broad subjects of modern petrology are discussed briefly. It is pointed out that, while no one sequence of types is generally applicable, the sequence seems to vary with the magmatic character and usually closes with basalts, though any generalizations must be rather hazardous owing to the inherently accidental character of the rock sequences observed by us. A change in the character of the magma and in the volcanic cycles seems to be connected with a change in the mode of volcanicity, the relation being possibly a causal one, but the inadequateness of present data for such studies is pointed out. The so-called Atlantic and Pacific tribes of rocks are briefly discussed and objections raised against them, it being urged among other things that it is illogical and unjustifiable to select only two types for contrast to the exclusion of others equally important. In conclusion, the importance of further and more detailed systematic study of volcanoes, the need of numerous chemical analyses, the importance of the application of physico-chemical research to petrological problems, and the magnitude and complexity of such future investigations, are insisted on.

(19) The hydrothermal formation of silicates, a review. George W. Morey and Paul Niggli. J. Am. Chem. Soc., 35, 1086–1130. 1913.

This is a discussion of the theoretical principles underlying the behavior of water-silicate systems at temperatures ranging up to 500°, followed by an annotated bibliography in which are assembled all of the data relating to hydrothermal syntheses. These data unfortunately afford practically no reliable quantitative information; qualitatively, even, they leave much to be desired, for many minerals have been obtained but once by a given investigator, in a manner which was not reproducible and under conditions which were not specified. The minerals which have been most commonly obtained are chiefly those which are stable—or at any rate phanerostable—over a wide range of conditions; for example, quartz and the feldspars. In all cases the crystals obtained are very small, so that accurate chemical analysis is usually out of the question; their identification by optical methods may even be doubtful.

Hydrothermal syntheses, like the paragenetic relationships investigated by van't Hoff, are determined by the solubility relations of all the possible solid phases which may be formed from the components present in the solution, even although the concentration of these components in the solution is vanishingly small. Many of the reactions are, without doubt, practically restricted to the solid phase, although they take place through the medium of the solution. These solubility relationships are thus not simple; but study of the question is further complicated by the frequent appearance of metastable phases, a phenomenon which is coordinated with the rates of the various possible reactions. Now, as is well known, rates of reaction are often affected very greatly by factors which in other respects are of altogether minor importance; hence slight differences (*e. g.*, in the composition, or even in the texture or fineness of grain, of the initial solid phase) may exert considerable influence on the result. These considerations serve to show that there may in certain cases be difficulties in the way of always being able to reproduce a given result; in order to do this in any case, it is necessary to control carefully the amount of water relative to the volume of the containing vessel (the degree of filling), the temperature, and, if possible, the

pressure also. The critical point of water is only a secondary factor in determining the nature of the product, its influence being effected principally through the change in concentration of the solvent (liquid or fluid) in the neighborhood of the critical point.

The thorough investigation of hydrothermal syntheses is beset with many difficulties, apart from the technical problems inherent in operating on heterogeneous systems within closed bombs at high temperatures. Nevertheless our knowledge of the real relationships of these minerals can be advanced materially if care is taken to control the factors involved, the most important of which are the initial composition of the system (including therein the relation between the amount of water and the volume of the bomb) and the temperature.

(20) Die hydrothermale Silikatbildung. Paul Niggli and George W. Morey. Z. anorg. Chem., 83, 369–416. 1913.

A German translation of "The hydrothermal formation of silicates" (Jour. Am. Chem. Soc., 35, 1086–1130, 1913). Reviewed under No. 19 above.

(21) Geophysical Research. Arthur L. Day. Smithsonian Annual Report for 1912, pp. 359–369.

Presidential address delivered at the seven hundredth meeting of the Philosophical Society of Washington, November 25, 1911, and printed in the Journal of the Washington Academy of Sciences (1, 247–260, 1911), for December 4, 1911. This address has now been reprinted, by permission of the Journal of the Washington Academy of Sciences, in the Annual Report of the Smithsonian Institution for 1912.

(22) The stability relations of the silica minerals. C. N. Fenner. Am. Jour. Sci. (4), 36, 331–384. 1913.

The relations between the mineral species quartz, tridymite, and cristobalite have been found to be enantiotropic. The inversion-temperatures under atmospheric pressure are

$$870^\circ \pm 10^\circ \text{ quartz} \rightleftarrows \text{tridymite}$$

$$1470^\circ \pm 10^\circ \text{ tridymite} \rightleftarrows \text{cristobalite}$$

The velocity of transformation of one form of silica into another has been found to be very slow and in many cases the process follows Ostwald's rule—that is, an unstable form does not pass directly into the most stable form, but the action progresses through successive steps, and intermediate phases appear which eventually reach the stage of greatest stability. The appearance of unstable phases in this manner has suggested an explanation of natural occurrences of tridymite and cristobalite under conditions which preclude the idea of their deposition within their range of stability, and an inquiry has been directed toward the circumstances attending their formation.

The preparations of artificial tridymite and cristobalite which have been made have yielded the minerals in very pure form and a redetermination has been made of a number of their optical and other physical constants. The relations of chalcedony have been investigated and evidence has been obtained tending to show that it is a distinct mineral species.

New determinations of the α–β inversions of the several species have given the following results:

α-quartz $\longrightarrow$ β-quartz 575°.
β-quartz $\longrightarrow$ α-quartz 570°.

α-tridymite $\longrightarrow$ β_1-tridymite 117°.
β_1-tridymite $\longrightarrow$ β_2-tridymite 163°.
Reversions on cooling not very sharp.

α-cristobalite $\longrightarrow$ β-cristobalite 275° to 220°, depending upon previous heat-treatment.
β-cristobalite $\longrightarrow$ α-cristobalite 240° to 198°, depending upon previous heat-treatment.

A study of the remarkable variations in the temperature of inversion of α- into β-cristobalite has led to the conclusion that this mineral is made up of two different molecular species of silica within the same crystal. Various other properties of the silica minerals seem to have considerable bearing upon theories of the structure of molecules and crystals. The nature of the radical differences existing between the two different types of inversion has been discussed in some detail.

The melting-point of cristobalite has been found to be close to 1625°. Quartz melts at least 155° lower.

(23) Die Stabilitätsverhältnisse der Kieselsäure Mineralien. C. N. Fenner. Z. anorg. Chem., 1914. (In press.)

A German translation of "The stability relations of the silica minerals" (Am. Jour. Sci. (4), 36, 331–384. 1913). Reviewed under No. 22 above.

(24) The general principles underlying metamorphic processes. John Johnston and Paul Niggli. J. Geol., 21, 481–516, 588–624. 1913.

This paper is an endeavor to set forth the most important general principles concerned in rock metamorphism—a general term which includes a number of special cases (*e. g.*, contact metamorphism), all of which, however, differ only in the degree of predominance of one (or more) of a definitely limited group of effective factors. These factors are: temperature, uniform pressure, stress (non-uniform pressure), and gross composition of the system at the time of metamorphism; the same, namely, which determine the equilibrium of the relatively simple chemical systems hitherto investigated experimentally. The knowledge gained from a study of these simple systems may be used as a basis for a prediction of the general character and significance of metamorphic processes; though in applying the principles one must always bear in mind those circumstances which oppose the attainment of a state of true equilibrium, such, for example, as slowness of reaction or the formation of metastable intermediate products.

Now, although the general character of the process may be predicted, no particular statement as to the effects produced in a given system by change of any of the above factors can yet be made, owing to lack of the requisite quantitative data. In this connection, it is to be noted that the general application of experimental results which obtain for a given system under given external conditions, to another system under similar conditions, or even to the same system under widely differing conditions, is subject to considerable limitation. Conclusions drawn from such extrapolation of experimental evidence will commonly be of little value, and may be alto-

gether misleading; moreover, one may as well guess the final result as arbitrarily choose the data required in calculating it. From this we see that the application of the above simple principles which determine rock metamorphism to the complicated rock systems will be no simple matter, but will require extended experimental investigation and a long time. In such investigation the first thing necessary is a definite conception of the general processes of rock metamorphism; this it was the purpose of the authors to present. The choice of particular problems in this large field will doubtless be aided greatly by a study of natural mineral associations from the physicochemical standpoint, a study which at the same time will certainly provide us with information bearing directly on the problems at issue.

(25) Einige physikalisch-chemische Prinzipien der Gesteinsmetamorphose. John Johnston and Paul Niggli. Neues Jahrb. Min. (In press.)

A German translation of "The general principles underlying metamorphic processes" (Jour. Geol., 21, 481–516, 588–624, 1913). Reviewed under No. 24 above.

(26) The physical chemistry of Seger cones. Robert B. Sosman. Trans. Am. Ceramic Soc., 15, 482–498. 1913.

The relation of certain simple principles of physical chemistry to the behavior of the Seger pyrometric cones, which are widely used in the ceramic industry for the indication of heat effects in the kilns, is illustrated by experiments and charts. The high-temperature cones Nos. 28 to 42 form a simple two-component series composed of alumina and silica. Their behavior agrees well with the known properties of this system, taking into account the three retarding influences: (1) lack of initial homogeneity, (2) slow rate of fusion of silica, and (3) high viscosity of the melt. Cones 5 to 27 are made up of four oxides. It is possible to discuss them, however, as a three-component system of orthoclase, calcium silicate, and aluminum silicate, with excess silica as a relatively inactive addition. In this system, as in the foregoing, the control exercised by the low-melting eutectics upon the indications of the cones is well brought out.

(27) The phenomena of equilibria between silica and the alkali carbonates. Paul Niggli. J. Am. Chem. Soc., 35, 1693–1727. 1913.

This is a record of an experimental investigation of the equilibrium between silica and melted alkali carbonate, at temperatures of 900° to 1000° and under a pressure of 1 atm. carbon dioxide. A series of experiments was made with the carbonates of potassium and sodium, and a few with lithium carbonate. The systems R_2O–SiO_2–CO_2 ($R = K, Na, Li$) under the above-mentioned conditions behave similarly on the whole and differ only in details. Silica added to alkali carbonate is transformed into silicate as long as any carbonate remains. In the melts there is equilibrium between carbonate and pairs of silicates, as follows:

I. $K_2CO_3 + K_2Si_2O_5 \rightleftarrows 2K_2SiO_3 + CO_2$

II. $Na_2CO_3 + Na_2SiO_3 \rightleftarrows Na_4SiO_4 + CO_2$

III. (presumably) $2Li_2CO_3 + Li_4SiO_4 \rightleftarrows Li_8SiO_6 + 2CO_2$

The solid phases which separate from the melts consist of silicate or carbonate, but contain no free silica until the proportion of silica exceeds that corresponding to the higher silicate. The amount of carbonate depends only on the ratio R_2O/SiO_2, when external conditions are constant; when

this ratio becomes identical with that of the silicate richer in silica, the melt is free from carbon dioxide. In each case the compound containing more silica is the poorest in silica which can be prepared pure at the particular temperature merely by putting together carbonate and silica. Moreover, rise of temperature, the pressure remaining constant, favors the lower silicate.

The study of systems of this type is important because their behavior serves as a simple prototype of that of the magma, which is a highly complex system containing both volatile and non-volatile components. The so-called "mineralizers" are merely volatile components; the effects of their presence differ only in degree from that of the other components. The main difference is due to the vastly greater effect of changes of pressure and of temperature on the concentration (in the melt) of the volatile component, by reason of the close relation of the concentration to that of the gas phase itself. In consequence of this, there is a "mobility" of equilibrium which is characteristic of the magma and without doubt very closely associated with many aspects of its behavior, *e. g.*, with the likelihood of eruption, differentiation, etc.

(28) Gleichgewichtserscheinungen zwischen Alkalikarbonaten und Kieselsäure. Paul Niggli. Z. anorg. Chem., 84, 229–272. 1913.

A German translation of "The phenomena of equilibria between silica and the alkali carbonates" (J. Am. Chem. Soc., 35, 1693–1727. 1913). Reviewed under No. 27 above.

(29) The electrolytic reduction of iron for analysis. J. C. Hostetter. J. Wash. Acad. Sci., 3, 429–432. 1913.

The conditions for the complete electrolytic reduction of ferric sulphate to ferrous are discussed and some results are presented to show the convenient application of the method to the determination of iron.

(30) The volcanoes and rocks of Pantelleria. Henry S. Washington. J. Geol., 21, 653–670, 683–713. 1913.

The island of Pantelleria was studied in September 1905, under Grant No. 95, and the paper describes both the volcanic structure and the petrography of the very interesting lavas.

Pantelleria (which lies about half-way between Tunis and Malta) is entirely volcanic. It consists of an early, large cone, composed of trachytes and pantellerites. After a large explosive caldera was formed in this, a second volcanic phase began, consisting of the building up of a trachyte core within the caldera. Later this was faulted and a large block tilted down, smaller cones and flows of glassy pantellerite being poured out about this. Volcanism ceased with the formation of many small basaltic cones on the flanks of the earliest cone.

The important lavas are described in great detail, 17 complete chemical analyses having been made. The trachytes and pantellerites are interesting because they carry abundantly well-developed crystals of soda-microcline, an unusual feldspar, the crystals of which are to be investigated optically and chemically later. The latter rocks are also noteworthy for their content in the rare triclinic, sodic amphibole, cossyrite. The basalts are of a common type, but their occurrence here in connection with such highly sodic rocks is of interest.

The relations of the lavas to the volcanism were examined, and there is a probable connection between the successive changes in the magma and the phases of volcanicity, a feature apparently here recognized for the first time. Such a connection would be of great volcanologic importance, and as there is evidence of its obtaining at other volcanic centers, it will form the subject of future investigation.

The analyses of these rocks made by the author show that all the earlier analyses, which have been very often cited, are subject to serious analytical errors. The paper closes with a comparison of the Pantellerian lavas with those of other regions.

(31) Graphical methods in microscopical petrography. Fred. Eugene Wright. Am. Jour. Sci. (4), 36, 509–539. 1913.

Experience in microscopical petrography has shown that the results furnished by graphical means are, as a rule, sufficiently accurate and in accord with the quality of the data of observation. Graphical methods in petrography serve three purposes: (1) to solve certain equations, (2) to represent data of observation, and (3) to picture certain important crystallographical and optical relations. In all these cases it is essential: (*a*) that the graphical means employed represent the relations adequately and as free from distortion as possible; (*b*) that they are easy of application; and (*c*) that wherever possible the functions be plotted in such a form that their changes can be represented by straight lines. Eight plates, drawn on these principles, are included, and furnish solutions for the following equations:

$$\sin i = n \sin r \qquad \sin^2 i = n^2 \sin^2 r$$

$$\frac{\gamma^1 - \alpha^1}{\gamma - \alpha} = \sin \vartheta_1 \sin \vartheta_2 \qquad \tan^2 V_a = \frac{\frac{1}{\beta^2} - \frac{1}{\gamma^2}}{\frac{1}{\alpha^2} - \frac{1}{\beta^2}} \qquad \tan V_a = \sqrt{\frac{\frac{1}{\beta^2} - \frac{1}{\gamma^2}}{\frac{1}{\alpha^2} - \frac{1}{\beta^2}}}$$

$$\cot A = \sin B . \cot C \qquad \sin A = \sin B . \sin C$$

(32) A graphical plot for use in the microscopical determination of the plagioclase feldspars. Fred. Eugene Wright. Am. Jour. Sci. (4), 36,540–542. 1913.

On this plot the changes in the optical properties of the plagioclase feldspars with chemical composition are indicated by a set of curves, the purpose being to furnish the petrologist, in convenient form and on a single sheet, all the constants essential for the accurate determination of the plagioclase feldspars in thin rock sections. A new set of curves for the extinction angles on sections showing symmetrical carlsbad-albite twinning is included, the values having been derived from the best available measurements on plagioclase feldspars.

(33) Magnetite basalt from North Park, Colorado. Henry S. Washington and Esper S. Larsen. J. Wash. Acad. Sci., 3, 449–452. 1913.

This basalt occurs at North Park, forming blocks in a breccia. It is quite unique because of the exceptionally high content in iron ore (55 per cent). A brief description of the results attained with the microscope is given, and a very complete chemical analysis. The basalt differs radically from other igneous rocks high in iron ores in being a lava and not part of an intrusive mass, and also in the very small amount of titanium which it contains.

(34) Some lavas of Monte Arci, Sardinia. Henry S. Washington. Am. Jour. Sci. (4), 36, 577–590. 1913.

This extinct volcano was visited in October 1905, in connection with Grant No. 95 from the Carnegie Institution of Washington. It has not been described since 1857. It is shown that the volcano consists of a core of rhyolite, with later flows of dacite, andesite, and trachyte, closing with extensive sheets of basalt, in many respects resembling the nearby and better known Monte Ferru. Detailed petrographic descriptions of the lavas are given, together with seven complete analyses. An apparently new mineral was found, which is to be further investigated. The paper is a preliminary one, and the volcano is worthy of another visit and fuller study.

(35) The determination of mineral and rock densities at high temperatures. Arthur L. Day, R. B. Sosman, and J. C. Hostetter. Am. Jour. Sci. (4), 37, 1–39. 1914.

The existing and rather conflicting data on the volume change of rocks on fusion are reviewed briefly. A method and apparatus is then described for the determination of the specific volume of metals or of solid or fused silicates from 200° to 1600°. The basis of measurement is the expansion of artificial graphite, which was determined from 20° to 1500°. Volume curves are given for tin, lead, and the eutectic of lead and tin.

Measurements were made on quartz up to 1600°. The volume of quartz increases more and more rapidly as 575° is approached. At this point the inversion takes place to the high-temperature form, whose volume decreases slightly with rising temperature. Between 950° and 1250° gases are given off. Above 1300° the volume is increased greatly by the formation of cristobalite.

Granite shows the same form of curve as quartz. Above 500°, however, it is not possible to obtain its true volume expansion because of the shattering and permanent dilatation due to unequal expansion of the minerals and to escape of gases. The same is true of crystalline diabase.

The curve of glassy diabase can be obtained, however. The glass crystallizes with contraction of volume at about 900°, then begins to fuse again at about 1150°. On cooling, the liquid again crystallizes with contraction. This behavior explains completely the results of Barus, which have been widely quoted. A recalculation of his data on the basis of a redetermination of his fundamental volume show them to be in good agreement with the new measurements. The bearing of these data upon the occurrence of "floated" slabs of rock in the Palisade diabase is discussed.

(36) Dichtebestimmungen bei hohen Temperaturen. Arthur L. Day, R. B. Sosman, and J. C. Hostetter. Neues Jahrb. 1914. (In press.)

A German translation of "Densities at high temperatures" (Am. Jour. Sci. (4), 37, 1–39, 1914). Reviewed under No. 35 above.

(37) New crystalline silicates of potassium and sodium; their preparation and general properties. George W. Morey. J. Am. Chem. Soc. 1914. (In press.)

Much work in the aggregate has been done on the action of water at 400° to 500° on minerals (compare abstract No. 19), but so far with very little really tangible result. The main reason for this lack of success is that the investigators worked with too complicated systems and did not control conditions with sufficient care. Accordingly it seemed desirable to examine, under carefully controlled external conditions, the simplest silicate systems; to discover, namely, what compounds form when silica is heated up with potash or soda in presence of water, and to determine if possible the limits

of stability of these compounds. The present paper treats of the mode of experiment, the general behavior of the above two systems, and the preparation of four new crystalline silicates; namely, $K_2O.H_2O.SiO_2$, $K_2O.2SiO_2$, $Na_2O.2SiO_2$, and $Na_2O.SiO_2$, the general properties of which are described. The second of these is identical with the product obtained by Niggli from (dry) melts of potassium carbonate and silica (abstract No. 27); the fourth is identical with the product obtained by Niggli from melts of sodium carbonate and silica. It may be mentioned that the potassium silicate, which when dry melts at about 1015°, yields in presence of water in a closed vessel, at temperatures about 400°, perfectly fluid solutions containing from 8 to 30 per cent of water; this indicates that the melting-point of a (non-volatile) silicate may be lowered enormously in presence of a relatively small proportion of a volatile component such as water.

(38) Neue kristallinische Kalium und Natrium Silikaten; Ihre Herstellung und Allgemeine Eigenschaften. George W. Morey. Z. anorg. Chem. (In press.)

A German translation of "New crystalline silicates of potassium and sodium; their preparation and general properties" (J. Am. Chem. Soc., 1913). Reviewed under No. 37 above.

(39) Observations on the Daubrée experiment and capillarity in relation to certain geological speculations. John Johnston and L. H. Adams. J. Geol. (In press.)

Those who believe that meteoric waters are an important factor in the production of the phenomena of vulcanism must always face the problem of devising a plausible account of the manner in which accessions of water can be introduced into the magma. This difficulty they have endeavored to obviate by instancing an experiment of Daubrée, who found that water would pass through a porous sandstone against a certain excess counter-pressure of steam. This passage of water is, as Daubrée pointed out, a manifestation of capillary action; the authors show that this same effect may be secured by means of a much simpler experimental arrangement. Now capillary forces are effective only when there is a surface of separation within the pores; moreover, they diminish steadily with rise of temperature, and vanish at the critical point of the liquid. Consequently, the Daubrée experiment gives no ground for supposing that capillary forces would be effective in causing water to penetrate into deep-seated and highly heated rock-masses. This conclusion has been pointed out before; the purpose of the present paper is to enforce it, since the opposite, and erroneous, conclusion still frequently appears as an argument in favor of the likelihood of the introduction of water by means of capillarity into molten magmas. Even if we make the somewhat unlikely assumption of free-liquid surfaces far down in the rocks, any pressure producible by capillarity is in general likely to be small in comparison with the pressure due to the hydrostatic column, except in pores of such fineness that the amount of water that could flow through them is infinitesimal.

(40) Über den Daubrée'schen Versuch und Kapillarität in Bezug auf gewisse geologische Spekulationen. John Johnston und L. H. Adams. Centr. Min. (In press.)

A German translation of "Observations on the Daubrée experiment and capillarity in relation to certain geological speculations." (J. Geol., 1914). Reviewed under No. 39 above.

(41) Water and the magmatic gases. Arthur L. Day and E. S. Shepherd. J. Wash. Acad. Sci., 3, 457–463, 1913.

This paper is chiefly concerned with the identification of and the reactions between the gaseous ingredients set free by the liquid lava at Kilauea during

the summer of 1912. A successful attempt was made to collect these gases directly from the liquid lava at a temperature of about 1000° before they reached the atmosphere. The collection of the gas before it has become altered by combustion with air has proved to be an insurmountable difficulty hitherto, whether the gases were collected in tubes for analysis in the laboratory or studied at the point of emergence with the spectroscope. In either case, the gases were burned or were in process of combustion, and therefore could not reveal either the true identity or the original relation of the gases participating in volcanic activity below the surface.

In so far as the present reconnaissance yields final results, it shows that the gases evolved from the hot lava at the Halemaumau crater are N_2, H_2O, CO_2, CO, SO_2, free H, and free S; with Cl, F, and perhaps NH_3 in comparatively insignificant quantity. No argon was found, nor any of the other rare gases.

The chief conclusion, upon finding this group of gases in association at 1000° or higher, is that they can not be in equilibrium at that temperature and must be in process of active reaction among themselves; there can be no equilibrium, for example, between free sulphur and CO_2, nor between free hydrogen and SO_2 or CO_2.

This is a conclusion of rather far-reaching consequence, for it must mean that the relative proportions of the gases are constantly in process of local change—a fact which is supported by the very considerable differences between the analyses of the gases contained in different tubes which were filled at the same time. Since these reactions are strongly exothermic, it also follows that a very large and constantly increasing amount of heat is set free during the rise of the gases to the surface. In support of this it was also observed that when the quantity of gas set free was large, the temperature of the liquid lava in the basin was higher (July 6, 1912, 1185°); when the amount of discharged gas was small it was lower (June 13, 1912, 1070°), the quantity of lava in the basin remaining substantially the same.

Controverting a view recently put forth, H_2O was found to be present as such among the gases set free, as indeed it inevitably must be, for it has long been known that free hydrogen in association with SO_2 and CO_2 will react to form water at these temperatures.

Neither hydrocarbons nor chlorine in appreciable quantities were found.

The paper is somewhat preliminary in character and will be followed by more detailed studies of the relation of the gases to each other and to the lava at the temperatures which prevailed in the volcanic vent.

(42) L'eau et les gaz magmatiques. Arthur L. Day et E. S. Shepherd. Compt. Rend., 157, 958–961. 1913.

Abstract in French from "Water and the magmatic gases" (J. Wash. Acad. Sci., 3, 457–463, 1913.) Reviewed under No. 41 above.

(43) Conclusions à tirer de l'analyse des gaz du cratère du Kilauea. Arthur L. Day et E. S. Shepherd. Compt. Rend., 157, 1027–1030. 1913.

Abstract in French from "Water and the magmatic gases" (J. Wash. Acad. Sci., 3, 457–463, 1913). Reviewed under No. 41 above.

(44) Water and volcanic activity. Arthur L. Day and E. S. Shepherd. Bull. Geol. Soc. Am., 24, 573–606. 1913.

A somewhat more detailed discussion, with illustrations, of the subject-matter reviewed in No. 41 above, together with the data and the conclusions which may be drawn therefrom.

(45) The Geophysical Laboratory. Arthur L. Day. Trans Am. Ceram. Soc., 15, 49–54. 1913.

An informal address, delivered at the fifteenth annual meeting of the American Ceramic Society held in Washington on February 25, 1913, upon the general subject of the laboratory study of silicates.

(46) The change in the crystal angles of quartz with rise in temperature. Fred. E. Wright. J. Wash. Acad. Sci., 3, 485–494, 1913.

In this preliminary paper the results of the crystallographic measurement of quartz crystals at temperatures up to 1250° are presented. The crystals were measured in the electrical furnace attachment to the Goldschmidt two-circled goniometer (described above in Paper No. 17). The polar angle ρ (51° 47′3 at 20° C.) of the unit rhombohedron decreases at a constantly increasing rate with rise in temperature up to 575° ($\rho = 51°36′7$) at which temperature the α-quartz inverts into β-quartz. This is accompanied by an abrupt decrease of about 2′ in the angle ρ, which then, however, remains practically constant up to 1250°; it increases, possibly, very slightly, but the data of observation are not sufficiently accurate to determine the exact amount, which is of the order of magnitude of tenths of minutes.

A comparison of the changes in the crystal angles of quartz on temperature rise, with the changes in specific volume, thermal expansion, birefringence, circular polarization, and also excess of specific heat of quartz over that of a normal silicate without a low temperature inversion-point, shows that the differential changes between these properties are practically linear. A detailed correlative study of the changes in the crystallographical and physical properties of different minerals with change in temperature and pressure should lead to a better understanding of the forces which produce these changes.

(47) A useful type of formula for the interpolation and representation of experimental results. L. H. Adams. J. Wash. Acad. Sci., 3, 469–474, 1913.

It is often desirable, either for the sake of convenience in interpolation or in order to discover accidental errors in a series of observations, to express the results of an experimental investigation by some sort of empirical equation. For such purposes a power series—usually a quadratic or a cubic—is employed by many people even in cases where it is obvious that such a form of equation can not possibly fit throughout the entire range of the observations. It is therefore advisable always to choose an equation which conforms to the general character of the graph of the observations—a condition which in general is easily satisfied. For instance, an equation conforming to the condition that the graph in the limit approaches a straight line (a case of frequent occurrence in physical measurements) reproduces the thermo-electromotive force of copper-constantan couples over a large range of temperature much better and more conveniently than a power series containing a like number of constants.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. Franklin Jameson, Director.

The following report, the eighth annual report of the present Director, covers the period from November 1, 1912, to October 31, 1913. The regular staff of the Department has during the year been changed only by the accession of Dr. Charles O. Paullin, who in the preceding year had been connected with the work of the Department as a Research Associate, but in January 1913 became definitely a member of the staff. Dr. Paullin is to have general charge of all work upon the proposed Atlas of the Historical Geography of the United States. Professor Max Farrand, of Yale University, Research Associate, who in the last month of the preceding year had begun a period of assistance to the Department in the matter of economic and social geography, continued his aid through November and most of December. Another Research Associate, Professor J. S. Reeves, of the University of Michigan, aided the Department, also in respect to its atlas work, during some five weeks in November and December 1912.

In March the Director sailed for London to attend the International Congress of Historical Studies held there early in April, and after its conclusion spent nearly four weeks in England, Scotland, and Ireland, occupied with various business of the Department. Mr. Leland, sailing at the same time, also attended the congress and then, after a week or two in London, repaired to Paris, to continue the labors there which have occupied him at intervals, and during the major portion of his time, for the last six years. Miss Davenport, who had worked in Washington until June, sailed then to London, where she has since been continuing her work.

The Department has continued to occupy the same quarters which were entered upon at the close of the preceding year, a suite of rooms on the eleventh or highest floor of the Woodward Building. In the middle of June, as usual, its headquarters were removed to North Edgecomb, Maine, where the office work proceeded until the middle of September.

Statements respecting the general plans of the Department and the purposes which its operations are intended to subserve have been made in former reports. It may be proper to mention that, when honored with an invitation to deliver the annual lecture before the Trustees of the Institution on December 12, 1912, the Director took this occasion to make a public explanation, fuller than any hitherto

*Address: 1140 Woodward Building, Washington, D. C. Grant No. 862, $29,600 for investigations and maintenance during 1913. (For previous reports see Year Books 3-11.)

put forth, of the grounds upon which the work of the Department is based and of the fundamental ideas which have influenced its plans. This address, entitled "The Future Uses of History," was subsequently published in the "History Teacher's Magazine" for February 1913. Briefly expressed, the main purpose of the Department is to serve the interests of present and future makers of historical monographs and general histories, in proportion to the estimated importance of their work respectively, by the provision, in fields which are not already sufficiently covered by other agencies, of aids belonging to one or the other of two main classes—either books which guide the inquirer to the location or assist him in the use of bodies of historical sources, or books which themselves present in proper scientific form the full text of important historical materials. Thus the publications of the Department fall naturally into two classes, the one that of reports, aids, and guides, the other that of textual publications of documents. It is customary in these annual reports to consider, successively, first, the work of the past year, and then the plans for the ensuing year, each under two headings, designating the two classes of publication just described, and a third relating to the miscellaneous activities of the Department.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

Three volumes have been published by the Department during the year. The first, issued in November 1912, publication No. 90A, is the first volume of the "Guide to the materials for American history to 1783, in the Public Record Office of Great Britain," a volume of 346 pages, prepared by Professor Charles M. Andrews, of Yale University. This volume comprises a general introduction upon the Public Record Office, its system and contents, and an elaborate survey or list of the American material, for the colonial and Revolutionary periods, contained in what are technically called the State Papers, namely, the State Papers Foreign—and at the end of the period the beginning of the Foreign Office Papers—the State Papers Domestic and Home Office Papers, the State Papers Miscellaneous, and the Colonial Office Papers, the latter occupying the largest portion of the volume. A special feature of the book is the care with which the compiler, besides presenting the detailed lists which make the main substance of the volume, enters upon full explanations of the workings of the various offices, such as the Board of Trade and the office of the Secretary of State, by whose operations with respect to the colonies the papers under consideration in each section accumulated, and from which they have descended to the Public Record Office.

The natural complements to this book are the second volume, presenting descriptions and lists of what are technically called Departmental Papers and of other sections, completing the inventory of the Public Record Office so far as the period of American history prior to 1783 is concerned, and the volume by Dr. Charles O. Paullin and Professor Frederic L. Paxson, entitled "Guide to the materials in London archives for the history of the United States since 1783," publication No. 90B. Both of these volumes are now in press. They are complete in page-proof and are delayed from publication only by the necessity of preparing their indexes. Apart from the indexes, the former makes a volume of 555 pages, the latter one of 367 pages. Their issue will complete the series consisting of the books which have been named and of the "Guide to the manuscript materials for the history of the United States, to 1783, in the British Museum, in minor London archives, and in the Libraries of Oxford and Cambridge," by Professor Andrews and Miss Davenport, publication No. 90, issued in 1908. It may properly be said that no similar inventory of anything like the same extent, covering the archive materials which London possesses for the history of any other nation, has ever been prepared or issued. It is hoped that the resulting expansion and improvement in the work of historical writers in the fields covered by the series may be commensurate with the efforts that have been put forth toward supplying them with information on these archives, and it is believed that ultimately these effects will be produced.

The second and third of the three volumes mentioned as having been issued during the year were published just before the period reported upon came to its close. These are Professor Herbert E. Bolton's "Guide to the materials for United States history in Mexican archives," publication No. 163, long delayed by the difficulties of the index and by other obstacles, and Mr. David W. Parker's "Guide to the materials for United States history in Canadian archives," publication No. 172. These volumes were sufficiently described in last year's report.

During Mr. Leland's absence from Paris, the work upon the American materials in the archives of that city went forward under the effective charge of M. Abel Doysié. Since Mr Leland's return to Paris in April it has been closely pursued by him and under his supervision. Its progress has been furthered partly by direct research and partly by using the results which have been obtained by others who have been preparing under the auspices of the American Historical Association and under Mr. Leland's direction a calendar of all the documents in the French archives relating to the history of the Mississippi Valley. This enterprise is not conducted at the charge of the Carnegie Institution of Washington. Its expenses are

defrayed out of a fund subscribed to by historical societies and departments in the Mississippi Valley and others; but its progress is constantly helpful to the preparation of the Guide, of a different character and of a larger scope, which is being made by Mr. Leland for the Carnegie Institution of Washington. In direct research his operations have covered at the Foreign Office the series "Mexico, Correspondance Politique," to as late a point as the regulations of the Ministry permit, and the entire series Texas; also the most profitable portions of the series Russia, England, Vienna, and Denmark.

At the Bibliothèque Nationale Mr. Leland has examined the series Clairambault, at the Archives Nationales a portion of the series H_1. Embracing in one view the personal work of Mr. Leland and that of his assistants M. Doysié, Madame Vila, and Mlle. Mairesse, and comprising what has been surveyed both on our behalf and for the benefit of the Mississippi Valley calendar, it may be reported that about 1,040 volumes have been examined during the year. It is estimated that up to the present time about 6,000 volumes or cartons have been examined, completing the archives of the Ministry of War and several libraries, nearly completing the Bibliothèque Nationale and the archives of the Ministries of Foreign Affairs and of the Colonies, and finishing about one-half of the Archives Nationales and the archives of the Ministry of Marine.

Mr. R. R. Hill finished his work in Seville at the end of March and then returned to America. His engagements to teach in the University of California during the summer and at Columbia University during the autumn and winter have interfered with the working into shape for the printer of that portion of his data which is intended for publication, but much progress has been made in this direction. The section of the Archives of the Indies which he was sent in January 1911 to examine and which occupied him from that time to March 1913 was the section entitled "Papeles procedentes de la Isla de Cuba," a mass of papers transferred from Havana in 1888 and richer than any other subdivision of the archives in materials for the history of the United States. It proved to contain 934 legajos or bundles relating wholly or in part (mostly the former) to our history, and averaging more than 400 documents to the bundle. All of these bundles were examined by Mr. Hill during the period of his stay in Seville and all necessary notes taken for a general descriptive inventory which it is proposed to publish in the form of one large volume. Mr. Hill has finished the first draft of the description of 706 of the 934 legajos. Meanwhile, assistants, numbering from two to five during various portions of the period, have worked steadily under Mr. Hill's direction making an itemized list of all the documents in a body of 143 legajos selected as the most important. The total number of documents thus listed is 58,343. It is not thought that it

will be expedient to print these lists, but they will be retained in the office of the Department, where they can at any time be consulted by inquirers into Spanish-American history, and photostat copies of any series of them can be furnished at a cheap rate to investigators at a distance. The obliging kindness of Señor Don Pedro Torres Lanzas, chief director of the Archives of the Indies, and of his chief assistant, Señor Don José González Verger, and other assistants and of the American consul in Seville, Mr. Charles S. Winans, continued throughout the entire period of Mr. Hill's residence in Seville, and deserves grateful recognition on the part of the Department.

Mr. Hill also, with the Department's camera, specially constructed for archive use, made photographs of some 200 documents in the same section of the Archives of the Indies, selected as representative of what is historically most interesting in that section. The negatives of these photographs are in the office of the Department, and prints can be made from them for any libraries, archives, or individuals that may desire them.

In March Professor Albert B. Faust, of Cornell University, began a period of nearly six months of interesting activity on behalf of the Department, in the search for material for American history in the archives of German Switzerland and of Austria. Some of these archives have proved to be unexpectedly rich in American material, especially material relating to the process of Germanic migration to the United States. Beginning in Vienna, Dr. Faust found an especial abundance of material in the Haus-, Hof-, und Staatsarchiv, including reports to Metternich from the diplomatic representatives of Austria in the United States from 1819 to 1847, the date fixed as the limit for such investigations in Austrian archives. Materials in regard to emigration and commerce were also found here. In the Hofkammerarchiv papers respecting commercial relations were numerous. In the archives of the Ministry of the Interior the records of Metternich's police were particularly interesting. The archives of the Ministry of War and those of the city of Vienna also proved to be profitable. Grateful acknowledgments for facilities offered and courtesies extended are due to Hofrath Árpád von Károlyi and Sektionsrat Dr. Hanns Schlitter, director and vice-director of the first of the archives named, and to Dr. Ludwig von Thallóczy, Professor Dr. Heinrich Kretschmayr, General Woinovich von Belobreska, and Dr. Hermann Hango, directors of the second (Hofkammerarchiv), third, fourth, and fifth, respectively.

In Austria Dr. Faust likewise inspected the archives of Salzburg, from which occurred the great emigration of Protestants which has so much importance for the early history of Georgia, and those of Innsbruck. In Bern he found a mine of information in the Staatsarchiv, or archives of the canton, and in the Bundesarchiv or federal

archives (for the period since 1798), and expresses special indebtedness to Professor Dr. Heinrich Türler and Dr. G. Kurz, archivist and subarchivist of the former, and to Dr. Jakob Kaiser, director of the latter. Of the other cantonal archives those of Basel and Zürich seem to have contained the largest amount of material on Swiss emigration to America; but the archives of all the lesser German cantons were searched, and the whole history of the movement of population from German Switzerland to America was thoroughly inquired into. Everywhere the cantonal archivists showed cordial courtesy and deserve our best thanks.

While the Director was in Great Britain he made at Edinburgh preliminary inquiries as to a future report upon materials for American history in the general archives of Scotland. By the kindness of Professor P. Hume Brown he was able to make an arrangement for this purpose with Miss Margaret Adam, holder of a fellowship under the Carnegie Trust for the Universities of Scotland, whose special subject of investigation is the migration of Scotsmen to America. In the course of this investigation, which will necessarily range through the principal Edinburgh archives, Miss Adam will note all references of that sort which commonly make the staple of our Guides, and will thus provide us with the materials for a similar manual relative to the Scottish archives.

Preliminary inquiries of a similar sort into the national archives of Ireland were made by the Director at Dublin. He also, at the Public Record Office in London, made some examination of the books of the Royal African Company and of the Port Books of the English customs establishment, for possible future purposes.

The work of Professor Farrand and Dr. Paullin upon the Atlas of the Historical Geography of the United States consisted, during the former's period of residence, in the planning of the series of maps exhibiting the economic and social history of the country, and in the endeavor to locate the abundant but scattered materials for this purpose which are to be found in the government departments in Washington. During a part of the same period Professor Reeves and Dr. Paullin worked together upon problems connected with the mapping of the international boundaries of the United States and of the disputes respecting them since 1782. From January to June Dr. Paullin's work consisted first in preparing an elaborate project for the contents of the atlas, and then in constructing maps of states showing the votes at presidential elections. These successive maps are now completed so as to be ready for the draftsman, to the extent of at least a third of the States. In October, Dr. Paullin resumed this work. He has also prepared a paper on the materials for the atlas, to be read at the meeting of the American Historical Association in December, in the hope of eliciting profitable discussion of sources.

TEXTUAL PUBLICATION OF DOCUMENTS.

Dr. Burnett's work upon the projected series entitled "Letters of delegates to the Continental Congress" has been more or less interrupted by occasional duties in connection with other portions of the Department's activities, but on the whole he has been able to spend most of his time during the year in continuing the process of annotation. The annotations referring to the Journals have been completed; those having the nature of cross-references to our own materials have been carried through the year 1784 in all respects, and in some respects to the concluding date, the year 1789.

Miss Davenport has occupied herself continuously with her collection of "European treaties having a bearing on United States history." From November to June her work was carried on in the office of the Department at Washington, and consisted in reducing to final shape for publication the earlier portion of the first volume. In this work she had the assistance of Miss Sanderlin. Since her return to London she has been carrying out the same sort of work with respect to a further section of the treaties, and hopes to have the first volume of the work ready for print before long.

The series called "Proceedings and debates of Parliament respecting North America, 1585 to 1783," has during the year advanced in several particulars, though the advance has been less signal than might have been wished. The copying or cutting and mounting of the relevant entries in the Journals of the House of Commons has been carried throughout nearly the whole of the seventeenth century and more than half of those years of the eighteenth century which the book is intended to cover. Mr. Stock has carried down to 1752 the search for those portions of the Lords Journals which are desired. The search for printed texts of debates has made less progress. In respect to manuscript reports of Parliamentary debates, the Director was able to make some progress in discoveries during his visit to England in the spring and is indebted to Lord Lucas, to the librarian of Trinity College, Dublin, the librarian of Exeter College, Oxford, and the authorities of the Public Record Office for facilities offered in this endeavor; but he was unsuccessful in the attempt to trace the missing shorthand volumes of Henry Cavendish, corresponding to Egerton MSS. 215–263, which if discovered would be so valuable to the proposed compilation.

Mr. A. Percival Newton, of London, has, at the request of the Director, prepared for the Department a report upon the papers of the Royal African Company at the Public Record Office with reference to use which may be made of them in a later publication proposed by the Department. Whenever it becomes advisable to institute a series of volumes of documents relative to the history of the negro, the slave-trade, and slavery in America, considerable use must

be made of this section of the Public Record Office in respect to one of the sections of the proposed compilation.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the "American Historical Review" has been carried on in the office of the Department and by its staff. The lecture given before the Trustees in December, by the Director, has already been referred to, as also his participation in the quinquennial International Congress of Historical Studies at London, of which he was made one of the vice-presidents. In this congress he read a paper on "Typical Steps of American Expansion." Mr. Leland's supervision of the calendaring of the papers in the French archives relating to the history of the Mississippi Valley, for a group of American historical organizations, has been accompanied by various similar services rendered by him to the State of Mississippi, the Michigan Historical Commission, and various individual American investigators in Paris. The State of Illinois has published, as the chief component part of the "Report of the State Education Building Commission to the Forty-Eighth General Assembly," Mr. Leland's "Report on the public archives of historical interest to the State of Illinois with special reference to the proposed education building," made by him at the instance of the commission named. He has also prepared for the "Revue Historique" a general survey of recent American historical literature.

As in previous years, searches and copies have been made by the Department, or under its supervision, for various historical societies and for many individuals. Letters of inquiry as to historical papers in Washington and other matters have been answered with the usual freedom. The Director has, as a matter of course, done what he could in small miscellaneous ways to further the interests in Washington of the American Historical Association and of American historical scholars, and has endeavored to mediate between them and foreign archives and other remote sources of historical information whenever occasion arose. For instance, the Deputy Keeper of the English Public Records has been furnished with a copy of our list of eighteenth-century documents from English archives which have been printed in American historical works.

RETROSPECT, 1903-1913.

The definite establishment of the Department of Historical Research, then called Bureau of Historical Research, occurred in the autumn of 1903. It may therefore be appropriate to take the present occasion for a brief survey of the work which it has accomplished during its first ten years. Organized historical work on the part of the Carnegie Institution had, however, already begun in January 1903, when, under plans formulated by Mr. Worthington C. Ford,

Dr. Claude H. Van Tyne and Mr. Waldo G. Leland began a systematic search of the government archives in Washington and the preparation of a detailed report upon their contents. This was a task which stood first among the recommendations of the Advisory Committee on History. But that committee also recommended the establishment in Washington of an institute of historical research, which should organize such searches of archives in Europe and America, edit guides to those archives and volumes of documentary material, and serve as a clearing-house for the historical scholars of the country. In the autumn of 1903 such a bureau was organized, under the charge of Professor Andrew C. McLaughlin, to whom the Department owes all the gratitude that is to be won by a wise and careful laying of foundations for future work, as well as by two years of solid achievement. The present Director and most of the staff have served during the last eight years of the decade, while Mr. Leland's service has extended from January 1903 to the present time.

During the ten years (and the next few months) the Carnegie Institution of Washington will have issued on behalf of the Department the following publications, mostly volumes of from 300 to 500 pages, octavo:

Guide to the Archives of the Government of the United States in Washington, by Claude H. Van Tyne and Waldo G. Leland (1904, pp. xiii, 215; second ed., by W. G. Leland, 1907, pp. xiii, 327).

Influence of Grenville on Pitt's Foreign Policy, 1787–1798, by Ephraim D. Adams (1904, pp. 79).

Report on the Diplomatic Archives of the Department of State, 1789–1840, by Andrew C. McLaughlin (1904, pp. 73).

Writings on American History, 1903, by Andrew C. McLaughlin, William A. Slade, and Ernest D. Lewis (1905, pp. xiv, 172).

Guide to the Materials for American History in Cuban Archives, by Luis M. Pérez (1907, pp. x, 142).

Guide to the Materials for the History of the United States in Spanish Archives (Simancas, the Archivo Historico Nacional, and Seville), by William R. Shepherd (1907, pp. 107.)

Guide to the Manuscript Materials for the History of the United States to 1783, in the British Museum, in Minor London Archives, and in the Libraries of Oxford and Cambridge, by Charles M. Andrews and Frances G. Davenport (1908, pp. xiv, 499).

List of Documents in Spanish Archives relating to the History of the United States, which have been printed or of which Transcripts are Preserved in American Libraries, by James A. Robertson (1910, pp. xv, 368).

Inventory of Unpublished Material for American Religious History in Protestant Church Archives and Other Repositories, by William H. Allison (1910, pp. vii, 254).

Guide to the Materials for American History in Roman and Other Italian Archives, by Carl R. Fish (1911, pp. ix, 289).

Calendar of Papers in Washington Archives relating to the Territories of the United States (to 1873), by David W. Parker (1911, pp. 476).

Guide to the Manuscript Materials relating to American History in the German State Archives, by Marion D. Learned (1912, pp. vii, 352).

Guide to Materials for the History of the United States in the Principal Archives of Mexico, by Herbert E. Bolton (1913, pp. xv, 553).

Guide to the Materials for United States History in Canadian Archives, by David W. Parker (1913, pp. 339).

Guide to the Materials for American History, to 1783, in the Public Record Office of Great Britain.

Vol. I. The State Papers, by Charles M. Andrews (1912, pp. xi, 346).

Vol. II. Departmental Papers and Miscellaneous (1914, pp. 367+).

Guide to the Materials in London Archives for the History of the United States since 1783, by Charles O. Paullin and Frederic L. Paxson (1914, pp. 555+).

So extensive a series, brought out in the brief space of ten years, can not fail to have defects. It is hoped that the books will, in the main, stand well the tests of accurate scholarship. Yet if subsequent investigations, by ourselves or others, show that certain books or parts of books might have been much improved by spending much more time in their preparation, it should be remembered that the object of the Department was "to serve the present age," by bringing out such guides at as early a period as possible.

It will be seen that most of these volumes are inventories of archives, American or foreign, listing single documents or whole volumes that relate either to the history of the United States or to the whole history of English North America. It may be computed that they have called the attention of historical students to not less than 100,000 historical documents or volumes of manuscripts, nearly all of which were previously unknown to them. Most of the foreign archives important for American history, except the French, the Dutch, the Russian, and the Scandinavian, having been covered by such inventories, the first stage of dealing with foreign archives may well be regarded as now approaching its conclusion. Without entirely delaying further operations until the writers of monographs and general histories have more extensively used the treasures already disclosed to them, we may conclude that hereafter a greater portion of our energies and resources belongs to the textual publication of documents and to the Atlas and other labors lying wholly within the borders of the United States.

During the greater part of the ten years, however, continuous attention has also been given to three textual publications—the "Letters of delegates to the Continental Congress," the collection of "European Treaties having a bearing on United States history," and the "Proceedings and debates of Parliament respecting North America, 1585–1783." Each of these will consist of several volumes. For each, the materials must be obtained with difficulty and adjusted with great care. Their nature requires them to be products of slower growth than the inventories, and they have been slower in preparation than was expected, so that the decade ends without any of them having yet come to publication. But two of them are approaching completion and a third, upon which less effort has been expended, is perhaps half done.

The ten years have also seen the preparation, in the office, of ten volumes of the "American Historical Review," the writing of 20,000 or 25,000 letters, the continuous endeavor to assist historical societies, state historical departments, and serious historical investigators in all possible methods that can be pursued by such an organization, established in the capital city, in the neighborhood of the government archives and the Library of Congress.

In connection with this function of the Department as an historical clearing-house, it may be well to mention the accumulation in our office, as a by-product of work intended for publication, of matter not intended for that purpose or finally deemed unsuitable for it. Ten years have brought together a considerable store of such materials, which it is desirable that historical inquirers should have every opportunity to use. Such use is always permitted to students who come to the office, and opportunity for it can sometimes be given, by loan or by copies, to those who are at a distance. Therefore, it may be well, in a report intended for publication, to list the chief collections of this sort, as follows:

We have a collection, on some 40,000 slips, of notes of about that number of documents, in the English Public Record Office and other foreign archives, which have been published in printed volumes or of which manuscript copies exist in American libraries or other repositories. Of those of the former sort, the printed documents, there is also a separate list, available for loan. We have a list, on some 58,000 slips, of all the documents in 143 selected legajos relating to the history of the United States in the section of the Archives of the Indies at Seville called "Papeles procedentes de la Isla de Cuba." We have also copies of the extensive and itemized inventory of all the legajos of that subdivision, made in Havana at the time when the papers composing it were transferred from Cuba to Spain. We have the negatives of Mr. Hill's photographs of Seville documents. We have a body of cards analyzing large portions of the diplomatic and consular archives of the Department of State, with entries for each volume in many of the important subdivisions, and, throughout a considerable period of the English and French correspondence, for each despatch. We have also special reports on the archives of the Bahama Islands, of the British West Indies, of British Columbia, and of the Netherlands; a large collection of notes on the manuscript materials for American history preserved in North Carolina; and a more miscellaneous collection of similar notes on materials elsewhere.

In several cases historical scholars working in Washington with some assistance from this office have requited the aid by leaving with us duplicates of their sets of slips calendaring particular portions of the materials in the Washington archives which they have investigated. These are necessarily fragmentary, but will often be helpful.

Another class of data consists in notes taken for the purpose of being incorporated in certain of our publications, but subsequently excluded upon more strict definition of the scope of those volumes. Thus we have slips mentioning many territorial papers not included in Mr. Parker's "Calendar," and others representing Continental Congress materials not finally included in the scheme of Dr. Burnett's series. It should also be said that the materials of the books now in

preparation, such as the Atlas and the three textual collections, will during the long process of preparation of such volumes be always placed at the disposal of historical inquirers to the utmost extent which the work of the office upon these volumes will permit. The same is true of the proof-sheets of books still further advanced.

PLANS FOR 1914.

REPORTS, AIDS, AND GUIDES.

The first work of the Department, after the date at which the present report commences, should be the issue of Dr. Andrews's second volume and of the volume prepared by Messrs. Paullin and Paxson. These may very well appear early in 1914.

During the same period of November and December, sets of prints from the photographic negatives made by Mr. Hill in the archives of the Indies can be prepared and issued to the subscribers. This will give each a photographic copy of 200 documents selected by Mr. Hill as having the highest degree of historical interest. The finishing of his volume beyond the point which is reported above as having been already reached by him will necessarily be delayed in most respects until June by his teaching engagements at Columbia University. It may be hoped, however, that the summer will give him sufficient opportunity to complete the book.

Mr. Faust expects shortly to send the manuscript of his book upon the German-Swiss and Austrian archives. In the same volume will be incorporated the data which the Director obtained in the archives of the French cantons of Switzerland in the summer of 1912.

It is hoped that the year may be marked by further extension of work in the archives of the Indies. It is planned that Mr. Francis S. Philbrick, of New York, long familiar with those archives, may extend through part of the series Audiencia de Santo Domingo the same sort of descriptive listing of materials for United States history which Mr. Hill carried out in the "Papeles procedentes de la Isla de Cuba." It appears that, next to the last-named collection, the three Audiencias of Santo Domingo, Mexico, and Guadalajara are the most abundant in such materials; but exploitation of the last two, it is understood, has been undertaken by the University of California. At the same time when Mr. Philbrick is thus engaged, the period of the summer months, it is planned that M. Doysié, going down from Paris to Seville, shall carry through the making of a large series of photographs with the Department's camera, a series which it is believed will be strongly desired by a number of American archives, historical societies, and libraries. The endeavor will be made to photograph a continuous series in the Louisiana-Florida section, either the early portion of the despatches of the governor of Louisiana to his superior the captain-general at Havana, or the Reservada section in the same correspondence.

It is also planned that Professor William I. Hull, of Swarthmore College, shall, during the three summer months of 1914, make an inventory of the materials for American history in the Dutch archives, both national, provincial, and local. Ordinarily our books of this class have been confined to the central archives of each nation; but the report on the "Rijksarchief," which John Romeyn Brodhead made to the state of New York in 1847, was so elaborate, the documents which he listed have to so large an extent been printed by that state, and the amount of material acquired by the chief of the Dutch national archives since then has been relatively so small, that in the case of this country the most useful and appropriate task for the maker of an inventory is to search for and list the American material in the archives of the provinces, municipalities, and religious bodies. With these Professor Hull is already familiar by reason of the researches undertaken for his "History of the Quakers in Holland."

It is also intended that an expedition shall be made to the archives of St. Petersburg and Moscow, by Professor Frank A. Golder, of the Washington State College, who has for several years been much occupied with investigations into the history of Russian America and Eastern Siberia. By the kindness of Hon. Curtis Guild, until lately the American ambassador in St. Petersburg, the necessary permissions have been obtained from the Imperial Russian Foreign Office, and it is believed that no obstacle exists to the thorough exploration of whatever may be found illustrating the history of Russian America and the relations between Russia and the United States, in the Principal Archives of Moscow and in the archives of the Foreign Office and other ministries of St. Petersburg, extending as far down chronologically as the customary administrative regulations permit.

Miss Adam's undertaking in the Edinburgh archives has already been mentioned. As Mr. Leland expects to conclude in 1914 his long-continued, thorough, and systematic research in Paris, it may be said that so far as the central archives of each nation are concerned (and in some cases the provincial archives also) the preliminary work of describing in inventories the materials for American history in foreign archives has now been carried through or provided for in all the foreign archives important to American purposes, except those of Scandinavia, for which tentative arrangements have been instituted, and of Ireland.

Every effort will be made to make the largest progress possible upon the Atlas of the Historical Geography of the United States. Dr. Paullin will, it is hoped, have substantial aid from several members of the permanent staff of the Department, and such other assistance as it can afford to supply.

TEXTS.

Dr. Burnett will expend as large a part of his time as is possible upon the "Letters of delegates to the Continental Congress." Miss Davenport will give all her time to the book of treaties. It is hoped that much larger progress than in preceding years will be made in the volumes of "Proceedings and debates in Parliament respecting North America." The matter derived from the Commons Journals, the Lords Journals, and the Irish Journals can certainly be completed. The redaction of properly constituted texts of the debates on America from the various, and always more or less imperfect and discrepant, materials in existence is a work demanding high editorial qualifications and can scarcely be undertaken with full vigor until a special editor can be assigned definitely to the series. Yet some progress in the sifting of these versions and preparing them for the work of such an editor can probably be made, and it is hoped that early in 1914 Mr. Stock, having finished the work on which he is now engaged, may be able to take up the editing of this series.

Far from desiring that the work of the Department shall be stereotyped in a few efforts or confined to the few enterprises already undertaken, the Director plans various other publications useful to the historical profession. But it is easier to plan than to execute, and mention of them may be superfluous until our hands are more nearly free or there are other resources for undertaking them. It may, however, be well to say that the Department has a definite intention of proceeding, as soon as it can do so without detriment to the work now in hand, toward the preparation of a series of documentary volumes illustrating the history of negro slavery in America. This is a task of great importance, relating to the history of at least a tenth of our population, and bearing ultimately on one of the greatest problems of American life; yet no governmental commission, either federal or state, is, for well-known reasons, likely to undertake the scientific documentation of this portion of our history. But in the existing state of the Department's present work it would be premature to enter now upon details of this plan.

MISCELLANEOUS OPERATIONS.

The Department will no doubt maintain, in 1914, activities similar to those described above, under this heading, in that portion of this report which relates to the last twelve months.

DEPARTMENT OF MARINE BIOLOGY.*

Alfred G. Mayer, Director.

When the year began the prospects of the Department were never brighter, in the whole course of its past history, for the Trustees had generously authorized the expedition to Torres Strait, Australia; yet even before the month of January had passed the Department suffered an irreparable loss in the sudden death of George Harold Drew on the 29th day of the month. It was our hope that he might continue in the tropical Pacific the work he had so ably performed in the Atlantic, wherein he demonstrated that much, and indeed perhaps most, of the so-called coral mud of tropical reef regions is in fact not due to corals, but that it has been precipitated through the agency of a bacillus which is very abundant in the surface waters of the tropical Atlantic and which denitrifies the ocean, reducing the nitrates to nitrites and finally expelling nitrogen gas from the water. This action results in causing the calcium to combine with the carbon dioxide to form finely divided colloidal calcium carbonate. We do not yet know how universal this action may be, and it was Drew's expectation and our own that he might continue the investigation until all the great oceans had been studied, but death has dashed our hopes and the work of one of England's ablest young men of science has been completed in so far as his own effort to advance it is concerned.

Mr. Drew had just been appointed a Research Associate of the Department when death terminated his labors. We mourn him as a warm-hearted, cultured friend; one of civilization's finest products, and an ornament to the science of Cambridge University, his alma mater. Had he lived his name would have become great in science, but even as it is his life and service stand as an inspiration to us all, and our sense of loss is tempered by an appreciation of the culture that developed him and of the great nation of whose civilization he was but a product.

Another serious check was also destined to fall upon the Department, for the investigator, for the advancement of whose studies the Australian expedition had been especially planned, failed temporarily in health and has been forced to abandon the expedition. The expedition, however, goes forward, and D. H. Tennent, Hubert Lyman Clark, E. Newton Harvey, Frank M. Potts, of Cambridge, the Director, and our engineer, Mr. John Mills, started from San Francisco on July 23 and arrived at Thursday Island, Torres Strait, on September 1, and will there establish a temporary laboratory.

*Situated at Tortugas, Florida. Grant No. 863. $31,890 for investigations and maintenance during 1913. (For previous reports see Year Books Nos. 3–11.)

Professor Tennent will continue the studies upon the control of dominance in echinoderms, which he has been pursuing at Jamaica and at Tortugas. Dr. Harvey will continue the work upon the relation between cell penetration and stimulation, which he began at Tortugas. Dr. Clark will continue his well-known work upon echinoderms and their development, and it is hoped he will produce another of his authoritative memoirs upon this group. Dr. Potts will study the worms, and the Director will study the temperature reactions of corals and the embryology of certain forms, as suggested by Dr. Vaughan, and also the medusæ Siphonophora and Ctenophora. Some physiological investigations will also be continued and others commenced.

In addition to the four who have gone on the Australian expedition, the following-named investigators studied at Tortugas:

Dr. Paul Bartsch, U. S. National Museum, Washington, April 25 to May 7.
Dr. L. R. Cary, Princeton University, September 1 to October 15.
Mr. R. B. Dole, U. S. Geological Survey, June 9 to 18.
Dr. A. J. Goldfarb, College of the City of New York, May 29 to June 28.
Prof. E. W. Gudger, State Normal College, North Carolina, May 29 to June 28.
Mr. K. S. Lashley, Johns Hopkins University, April 26 to June 28.
Prof. W. H. Longley, Goucher College, Baltimore, May 26 to June 28.
Dr. E. E. Reinke, Princeton University, May 29 to June 28.
Prof. A. L. Treadwell, Vassar College, May 29 to June 28.
Dr. T. Wayland Vaughan, U. S. Geological Survey, May 19 to June 13.
Prof. John B. Watson, Johns Hopkins University, April 26 to June 13.
Mr. Stanley C. Ball, artist, Yale University, May 29 to June 28.

Attention should be called to the fact that conditions at Tortugas have changed in a manner adverse to the welfare of the laboratory. The United States Navy has finally abandoned Fort Jefferson, and thus our only means of communication with the mainland is cut off, and it now becomes necessary for the *Anton Dohrn* to make at least one trip each week between Key West and Tortugas. This seriously interferes with the employment of the yacht in her more important capacity as an adjunct to the scientific equipment of the laboratory. Moreover, these trips are very expensive, owing to the greatly increased cost of gasoline and to the necessity for hiring additional men in order that the laboratory may not be short-handed when the yacht is absent. It is thus almost impossible to find time in which the yacht may be used for oceanographic studies, pelagic work, and dredging, for which she is especially well designed.

In the opinion of the Director, these difficulties can best be met by gradually abandoning the Tortugas as a site for our principal land station and establishing a laboratory upon Jamaica. Such a laboratory could be maintained for very much less expense than the present station at Tortugas, and could be kept open throughout the year. This would permit the *Anton Dohrn* to be used exclusively upon an oceanographic and zoological cruise each year, while our Jamaica laboratory could depend upon the launches we already possess to supply it with material for its studies. Jamaica has been constantly becoming more and more accessible during the past ten

years and will be a most important port of call after the opening of the Panama Canal. In fact, it is destined to be to the Atlantic what Hawaii is to the Pacific—the centrally-situated island. Health conditions have also improved decidedly upon Jamaica within the past decade, and on the whole it appears, with its wonderfully rich marine fauna, good land fauna, and the deep-ocean water around it, to afford the best possible place for the most effective continuation of our studies. The laboratory we advocate the establishment of should become "the Naples of America."

Within five years it will become necessary to renew the older of our wooden laboratory buildings at Tortugas, owing to the rapid deterioration of such structures in a tropical climate, but instead of doing this, the Director recommends that concrete structures be built by native labor upon Jamaica, and that the laboratory be gradually moved so that at the end of about five years we may wholly abandon the Tortugas. The change does not contemplate any increase in the annual appropriations for the laboratory, for, owing to the low cost of labor and of food in Jamaica, the expense of maintaining a laboratory there should not be half as great as it is upon the Tortugas.

During 1914 it will be necessary for the Department to make a cruise to the Bahamas to revisit Golding Cay and the reefs of Andros Island in order that Dr. Vaughan may secure his data upon the growth-rate of Bahaman corals, the geologic history of the islands, and the formation of the oolite. It is the hope of the Director that this expedition may also serve to grant an opportunity for certain well-qualified investigators to conduct intensive oceanographic and ecological studies in the deep region of the Tongue of the Ocean. After this, the Tortugas Laboratory will be maintained open during the summer of 1914.

In 1915, however, the Director hopes to devote the entire season to an expedition to Jamaica, granting opportunities for research in their chosen fields to at least 15 students who have already attained distinction through their ability as investigators. This expedition would provide us with a definite basis upon which to calculate the expenses of the proposed change of base and the best manner of effecting it, should it finally be deemed advisable. We would also be able to determine the health conditions in summer, the best site for the proposed laboratory, and other important factors in the problem. Should the change be decided upon, the apparatus and parts of the buildings now at the Tortugas could readily be transported to Jamaica, thus materially reducing the cost of the project. In fact, the plan is not to establish a new laboratory, but merely to move our old one. Jamaica now has direct steamship lines to the United States, England, and Germany, and thus it would afford an ideal site for a truly international laboratory, the establishment of which Huxley long ago so eloquently advocated.

Many of the investigators this season at Tortugas worked upon researches which are to be published in the forthcoming volumes 5 and 6 of "Researches from the Department of Marine Biology," now in press. Owing to the necessity for shortening the season due to the Australian expedition, only persons who had in previous years studied at Tortugas came again this year to complete or to continue their investigations, the time being too short to permit of any satisfactory progress upon new researches.

Dr. Paul Bartsch revisited the Florida Keys and Tortugas, upon which, during May and June 1912, he had placed two forms of *Cerion* taken from the region of Golding Cay, Andros Island, Bahamas.* Young produced by these snails were found upon Ragged Keys, Bahia Honda, and the Tortugas, but in each case they resembled their parents in all respects and had as yet been unaffected by their changed environment. Dr. Bartsch has segregated these young upon Loggerhead Key, Tortugas, and will endeavor to determine whether the next generation still remains true to the ancestral type. Practically every islet of the Great Andros Archipelago has its own peculiar form of *Cerion*, and Dr. Bartsch's experiments are directed to determine the cause of this remarkable variability.

Dr. Cary will spend September and part of October at Tortugas in studying the embryology of *Palythoa*, the life histories of Hensen's and Semper's larvæ, and the growth-rate of Gorgonians.

Mr. R. B. Dole made determinations of the salinity and other chemical and physical factors of samples of sea-water which had been collected in the Tortugas lagoon and at other places by Dr. Vaughan. He found that the average salinity of Tortugas sea-water is about 36.15‰ and it is saturated to about 92‰ of its capacity with oxygen, but contains no free CO_2, the carbon dioxide being either fully combined or half combined. There is no detectable difference in the water in the middle of the lagoon at high tide as compared with the water at low tide, yet the salinity of the water in the lagoon remains constantly slightly higher than that of the general ocean surrounding it.

Dr. Goldfarb succeeded in fusing fertilized eggs of *Toxopneustes* and *Hipponoë*, producing in each species twin or multiple larvæ; his results will appear in one of the forthcoming volumes of Researches from the Department of Marine Biology.

Professor Gudger completed his anatomical studies of the eagle ray and made careful dissections of several species of sharks and teleosts, as described in his report.

Mr. K. S. Lashley served as assistant to Professor Watson, and himself carried out a research upon the sense of locality displayed by the gulls of Bird Key.

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*Figures of these two forms will be found in Smithsonian Miscellaneous Collections, vol. 60, p. 60, 1913.

Professor William H. Longley continued his elaborate study of the colors of the reef animals in relation to their general environment. He determined that yellow was the prevailing color, both of the reefs and of the reef-living animals. His suggestive and interesting report is herewith presented under his own name, and it is hoped his studies may be continued.

Dr. E. E. Reinke continued the studies upon the two forms of spermatozoa found in certain mollusks, devoting most of his time to *Strombus*. His results are concisely stated in the preliminary report he presents herewith, and he will publish an extended account of these studies in our forthcoming volume of Researches. It is hoped that he may continue his studies upon the interesting physiological aspects of this problem.

Professor A. L. Treadwell continued his studies of the annelids, devoting special attention to the Eunicidæ, the worms being drawn in color in a most careful and beautiful manner by Mr. S. C. Ball.

Dr. T. Wayland Vaughan continued his observations upon the growth-rate of the corals he had planted out in various places, and devoted much attention to obtaining samples of the water of the Tortugas lagoon and to a study of the processes which result in the formation of oolites. He also observed a remarkable analogy between the general contour and positions of the wide openings in the Marquesas and Tortugas atolls. Apparently, the same dominant factors of winds and currents have been at work upon both atolls. This observation makes an intensive study of the local currents of these regions very desirable.

Professor Watson continued his studies of the homing instincts of the noddy and the sooty terns of Bird Key, obtaining returns to their nests from Galveston, and from Mobile, Alabama. He also determined that if the birds be isolated from their nests for about 11 days they return when liberated, but at the end of about 14 days their mates commonly refuse to receive them, while after about 17 days of isolation the birds do not usually attempt to return to their nests.

Professor Watson, by other experiments, confirmed Professor G. Howard Parker's statement that a sound produced in the air is heard only faintly by an ear immersed beneath the surface of water. He also carried out an extensive study of habit-forming in the development of skill on the part of our men in shooting with bow and arrow.

Dr. Alfred G. Mayer continued the physiological studies begun last summer and found that if sea-water be diluted with distilled water, or with 0.9 molecular dextrose, the rate of nerve-conduction in *Cassiopea* increases, becoming most rapid in 90 per cent sea-water +10 per cent dextrose solution, or distilled water. It then declines, becoming normal in 80 per cent sea-water, after which it continues to decline in a rectilinear ratio as dilution increases. He also found that the magnesium of sea-water is not an active inhibitor of move-

ment, as had hitherto been supposed, but is chiefly, if not wholly, passive and inert, bearing much the same physiological relation to the sodium of the sea-water as nitrogen bears to the oxygen of the air. Three papers were prepared for the forthcoming volumes from the Department of Marine Biology.

It is a pleasure to acknowledge the highly appreciated gift, by the Museum of Comparative Zoology at Harvard College, of a nearly full set of its bulletins and memoirs. We are especially indebted to the curator, Dr. Samuel Henshaw, for this valuable accession to our library.

The following papers were published during the year as a result of studies upon collections made at Tortugas, Florida.

Über westindische Medusen, E. Vanhoffen, 1913, Zoologischen Jahrbuch, Suppl. 2, Heft 3, pp. 413–432, figs. A to D.
Observations in Mollusks among the Bahama Islands and the Florida Keys, by Paul Bartsch, Smithsonian Miscellaneous Collections, vol. 60, pp. 58–62.

The following reports on the recent researches at Tortugas are in press and will appear soon in publications 182 and 183 of the Carnegie Institution of Washington:

Drew, G. H.—On the Precipitation of Calcium Carbonate in the Sea by Marine Bacteria, and on the Action of Denitrifying Bacteria in Tropical and Temperate Seas.
Vaughan, T. W.—Preliminary Remarks on the Geology of the Bahamas, with Special Reference to the Origin of the Bahaman and Floridian Oolites.
Vaughan, T. W.—Building of the Marquesas and Tortugas Atolls and a Sketch of the Geologic History of the Florida Reef Tract.
Dole, R. B.—Some Chemical Characteristics of Sea-water at Tortugas, Florida.
Cary, L. R.—Observations upon the Growth-Rate and Œcology of Gorgonians.
Clark, H. L.—Growth-Changes in Brittle-Stars.
Tennent, D. H.—The Early Influence of the Spermatozoan upon the Characters of Echinoid Larvæ.
Jackson, Robert T.—Studies of Jamaica Echini.
Jordan, H. E.—The Spermatogenesis of the Mongoose; and a Further Comparative Study of Mammalian Spermatogenesis, with Special Reference to Sex Chromosomes.
Osburn, R. C.—The Bryozoa of the Tortugas Islands, Florida.
Mayer, A. G.—The Effects of Temperature upon Tropical Marine Animals.
Mayer, A. G.—The Relation between the Degree of Concentration of the Electrolytes of Sea-Water and the Rate of Nerve-Conduction in *Cassiopea*.
Mayer, A. G.—The Law Governing the Loss of Weight in Starving *Cassiopea*.
Goldfarb, A. J.—Changes in Salinity and Their Effects upon the Regeneration of *Cassiopea xamachana*.
Goldfarb, A. J.—Regeneration in the Annelid Worm, *Amphinoma pacifica*, after removal of the Central Nervous System.
Goldfarb, A. J.—Experimentally Fused Larvæ of Echinoderms with Special Reference to their Skeletons.
McClendon, J. F.—Experiments on the Permeability of Cells.
Harvey, E. N.—The Relation between the Rate of Penetration of Marine Tissues of Alkali and the Change in Functional Activity induced by the Alkali.
Jacobs, M. H.—Physiological Studies on Certain Protozoan Parasites of *Diadema setosum*.
Gudger, E. W.—The History of the Spotted Eagle Ray, *Aëtobatus narinari*, together with a Study of its External Structures.
Reinke, E. E.—The Development of the Apyrene Spermatozoa of *Strombus bituberculatus*.
Dahlgren, Ulric.—Origin of the Electric Tissues of *Gymnarchus niloticus*.

SPECIAL REPORTS OF INVESTIGATORS.

Report of Results of the Planting of Bahama Cerions on the Florida Keys, by Paul Bartsch.

In the annual report of the Director of the Department of Marine Biology of the Carnegie Institution for 1912 (Year Book No. 11, pp. 129–131) attention was called to the transplanting of a large number of two races of Bahama cerions to Florida Keys. We visited these plantations this spring and noted the following results:

On April 25 we visited the plantation on the second Ragged Key north of Sands Key, where 500 cerions of the "King's Road" type were planted. We recovered 260 of the planted specimens, all living, and two shells which had been partly broken by some animal in order to extract the flesh. These mollusks were found in the grass, on low bushes, and on the dead drift shrubbery. It is possible that the greater part of the planting might have been recovered if sufficient time had been devoted to it, as additional specimens were discovered every time we went over the ground where the planting was made. There was no need for doing this, however, since the collected material showed that the colony was in good condition.

The most interesting part of the visit to this colony was the finding of 11 young cerions which were born on this key; they were attached to a grass (*Gayoides imberbe*); of these, 3 were of similar size and much larger than the rest, which consisted of a little more than the nepionic whorls. Two of the larger young we took to Washington. These have 3.1 and 3.4 post-nuclear whorls, and agree in every way with the check series from the Bahamas. The rest we painted with black asphalt paint and left them in the originally planted colony.

The next visit was to the first Ragged Key north of Sands Key, where 500 cerions of the "White House" type were planted. Here most of the mollusks were attached to the stems and leaves of a densely matting, succulent plant (*Sesuvium portulacastrum*). The shells were hard to see, having the same color as the coarse coralline sand, and the fact that they were kept close to this by the trailing food-plant made it difficult to find them. Dead stumps, twigs, and bushes also formed a favorite habitat and in such locations the shells were usually found in clusters. On this key 220 of the planted specimens were recovered, all of them alive. Here we also found three young shells produced on the island, which were retained for closer laboratory study and comparison with the check series. These three shells have $1\frac{1}{3}$, $1\frac{1}{2}$, and 2 post-nuclear whorls, respectively, and agree in every way with the check series from the Bahamas.

On April 26 we visited the planting of 500 cerions of the "White House" type on Indian Key. Here they had been quite active, some having moved as much as 60 feet from the place where they had been planted. We recovered 245 in about an hour, and these were mostly on dead sticks and usually clustered, though a good many were found on *Sesuvium*. The vegetation has grown up so rank at this place that it now seems ill-suited for these organisms, and this may have been responsible for the great mortality among them, for we found 20 of the 245 dead—not a single young individual was observed. This, however, does not necessarily mean that none existed, for young cerions are exceedingly hard to find. We shifted the gathered specimens to the center of the island, which was drier and less densely covered with vegetation. The 225 living specimens were planted near the southern part of the west wall of the two foundation walls north of the

cistern, and marked with a stake. The dead shells were placed on the wall opposite the planting.

On April 27 we visited the planting of 500 specimens of "King's Road" type cerions on Tea Table Key. We found the place covered with a rank growth of a malvaceous plant which seems unsuited to the cerions, for they have left it and all have wandered inland, some as much as 100 feet. Most of them died on this journey. Of the 75 recovered, only 3 were alive. We planted these and also left the dead shells among some amaryllis plants, about 200 feet northwest of a cordia tree (*Cordia sebestina*), which is about 100 feet west of the old building, where the first planting was made. Last year the malvaceous plant was past the flowering and fruiting stage, giving the locality a most desirable aspect for a cerion plantation. No young were found.

On April 28 we paid a visit to the cerions planted on Bahia Honda Key, where 500 of the "White House" type were left last year. This place has been completely overrun by *Cenchrus tribuloides*, full of burrs, which made our search for cerions a rather trying one. Only 70 of the planted specimens were recovered, 7 of which were dead. No doubt many more could have been found, but this would have required a great amount of tearing up of vegetation and the enduring of a lot of misery, both undesirable at this time, since the only young specimens discovered were quite young, consisting practically of the nepionic whorls only. We planted the recovered lot opposite the tall palm above the mouth of the ditch and marked the place with a stake. On the same day we called at the planting on Duck Key, where 500 of the "King's Road" type were left. Here we found that the cerions had become quite scattered. We recovered 125, all of which were living, and were up in the grass and shrubbery, but not a single young specimen was to be seen. The dense grass made it difficult to find the shells, but as no dead specimens were found, we may consider that the colony is doing well. We replanted the whole batch near the old plantation and marked the place with a stake.

We next visited the plantation of 500 of the "King's Road" type made in the middle of New Found Harbor Key, and recovered 145, some of which had moved fully 50 feet from the place where they were planted; 14 of these were dead. Here the grass was so densely matted and luxuriant that it was difficult to find the specimens, which were quite generally distributed. No young were found. We replanted the recovered material on the ridge of the middle of the south side of the island, near the previous planting, fearing that the low central section might be subject to inundation, in case of heavy storms; the new place was marked with a stake and two cross-marks were cut into a coconut tree nearby.

On May 1 we stopped at Boca Grande and looked over the cerion planting, where 500 of the "King's Road" type were left last year, under the United States Coast Survey beacon. We recovered 128 from the very dense vegetation, only 2 of which were dead. No young were found. We replanted the lot a little inside of the inner side of the beacon, and marked the place with a stake.

On May 2 we visited the cerion plantation on Garden Key, where 138 of the "King's Road" type were left a year ago. The ground at this place was covered with a rank growth of morning glory (*Ipomœa pes-capræ*). I cleared a space of 10 by 20 feet by use of a pocket knife, and recovered 62 of the planted mollusks. I understand that some persons visiting this key had discovered this planting and collected some of the specimens, and, although they were asked to replace them, it is quite possible that this may

not have been done. A single young specimen was also discovered, showing that they have been breeding here. We transplanted the whole lot to the inside of the fort, pretty well in the center, where the conditions appear to be much more favorable than at the last place, and now that the fort is about to be abandoned little fear of interference with this colony need be expected. The place where the planting was made is nearest the house, just after leaving the trees on the main path from the entrance to the house; on the left side of the path we marked the place with a stake; 60 of the 62 found were alive; the two dead specimens had been crushed by something which had evidently preyed upon them.

Only 8, and no young, of the 72 small painted cerions planted on Bird Key were found, and it is more than probable that this little colony will not be successful.

On Loggerhead Key three plantings were made which may be referred to as the northern, the middle, and the southern. The northern consisted of 500 of the "White House," type; the middle consisted of a mixture of 500 each of the "White House" and "King's Road" type, while the southern was composed of 500 of the "King's Road" type. The northern planting is largely in a cactus patch (*Platopuntia*), and it was necessary to uproot a lot of these plants in order to hunt for the shells. The animals were doing well and 82 young were secured without much difficulty; 7 of the largest of these were taken to Washington for comparison with the check series, with which they agree in every particular; the largest specimen has seven post-nuclear whorls. The southern planting is situated in a sandy plain, covered with a stiff grass, and this seems to be an ideal condition for these organisms. Here I gathered 55 young in 20 minutes in a space of 3 square yards. The young were all about the base of the tussocks of grass, and some on the ground. I did not disturb the planted material. In all I secured 82, of which 7 were taken to Washington; these are all small, the largest having a little more than four post-nuclear whorls, but they agree in every way with the check series. This is by far the most flourishing of all the colonies. The middle colony is in a dense cactus patch, mixed with rank grass and some brush. An hour's hunting revealed no young specimens, and from the experience obtained at the southern planting, where many of the young are near the ground or on it, it was deemed best not to disturb this planting at the present time, but to wait until next year, when the young will have attained a larger size, or probably maturity, before making an exhaustive study of this colony. At the light-house dock on the west side I noticed that several dead shells of the cerions planted were occupied by hermit crabs, and although conditions like this were not observed in any of the other colonies, it seems possible that some of the shells may have been carried away in this manner.

On April 13 plantings of the young of the two races of cerions produced on Loggerhead Key were made in cages near the laboratory; 50 of each type were put in a fine-wire-screened cage in which suitable plants had been placed, while in a third cage 25 of each were placed, thus giving these a chance to cross if they will do so when they attain maturity.

The results so far obtained seem to indicate that the first generation will be like the parent generation unless decided changes should take place in the later whorls, which have as yet not been developed. The largest specimens found so far have only seven post-nuclear whorls, leaving two to three whorls still to be developed, and these make up fully half of the length of the shell. If the present tendencies prevail in the adult shell, then we can see that the somaplasm has not at once responded to the change of environ-

ment. The reaction of the germ-plasm to the changed environment will have to wait for its interpretation until the next generation presents itself.

Looking over the entire plantings, I am inclined to believe that, with the exception of the Tea Table and Indian Keys, the colonies are doing as well as might be expected. It is also quite possible that when the young in the various colonies attain a larger size a good many more will be found in the various places—in fact, a good many may be present in places where we did not discover them at all, for the nepionic shells are quite small and hard to find.

Birds observed on the Florida Keys on April 25 to May 9, 1913, by Paul Bartsch.

While visiting the cerion plantations this spring on the Florida Keys I had occasion to note the birds seen on and about the various islands between Miami and the Tortugas. I kept a list of these in my journal, believing that some of the notes might be of interest to ornithologists, particularly to the students of bird migration. I have made an extract of the bird notes and offer them for whatever they may be worth.

April 25.—Visited Sand Key and the Ragged Keys just north of this. Saw brown pelicans, man-of-war birds, royal terns, least terns (3 specimens), Bahama red-winged blackbirds, Cape May warbler, ground dove, kingbird,* Louisiana heron, and several cormorants.

April 26.—Between Cape Florida and Indian Key we saw a good many royal terns and a few brown pelicans and man-of-war birds. On Indian Key we found a colony of boat-tailed grackles breeding in the trees about the ruins of the old house; a red-bellied woodpecker was noted among the coconut trees.

April 27.—On Tea Table Key red-bellied woodpeckers were seen about the coconut trees and a kingbird among the agaves. A snowy heron and several green herons and a spotted sandpiper were seen on shore; brown pelicans and royal terns were also present.

On Knight's Key brown pelicans, royal terns, and laughing gulls were seen off shore, and about 25 least terns were flying about the sand-spit. An egret was seen at the edge of the mangrove thicket, where it remained the greater part of the afternoon and all through the night. On shore we noted kingbirds and boat-tailed grackles.

April 28.—Saw a colony of boat-tailed grackles breeding on the key east of Bahia Honda. In the afternoon we visited New Found Harbor Key, where we saw a large flock of bobolinks, all males. There was also a breeding colony of boat-tailed grackles on this island, and the brown pelicans and laughing gulls were fishing off shore.

April 29.—On both Saddle Hill Key and Geiger's Key brown pelicans, royal terns, male bobolinks, and Bahama red-winged blackbirds were seen.

April 30.—Visited La Breeza and Martello Tower, Key West, where four young men were engaged in trapping male bobolinks. They were using an ordinary square box-trap made of sticks held in place by a bow over the top and propped up with a stick, to which a long string was attached; under the trap canary seed was placed. The bobolinks were then rounded up by one of the young men, while the other guarded the distal end of the

*I am strongly inclined to believe that this bird is the gray kingbird, but not having a gun to enable me to collect specimens I was unable to decide this point positively. However, judging from the note, I am inclined to believe that the kingbird of the Florida Keys is the gray form.

string. The birds were actually driven to the traps and while partaking of the seed under them the string was pulled. Two of the men caught nine in the course of the morning. They told me that they also obtain nonpareils in the same manner, and other birds by trapping them in the bush. The bobolinks are used for caging and are said to bring 25 to 35 cents apiece, while the nonpareils in full plumage command as much as $1.25.

May 1.—Between Key West and Tortugas we noted a booby, also man-of-war birds and royal terns. Bird Key, Tortugas, had been taken possession of by the usual swarm of sooty and noddy terns, and there were also a few laughing gulls, man-of-war birds, and royal terns. The latter seemed to be quite partial to the stakes and buoys of the region, most of which had one or more of these birds resting upon them. On a trip through Loggerhead Key, from the station to the light-house, I noticed osprey, marsh hawk, Florida red-shouldered hawk, sharp-shinned hawk, pigeon hawk, and probably a broad-winged hawk. These birds of prey were certainly very well represented here, and Dr. Watson tells me they have raised a great disturbance among the terns on Bird Key. I also noticed barn swallows, which were resting on stakes and on the sand on the outer beach, looking quite tired. A water thrush and a redstart worked about the laboratory.

May 2.—Paid a visit to Bird Key, where, among the usual denizens, we also noted male and female black-poll warblers. We next visited Fort Jefferson on Garden Key. Inside of the fort we saw a pair of sharp-shinned hawks, quite a number of redstarts, several olive-backed thrushes, 2 male scarlet tanagers, a small flock of male bobolinks, a yellow palm warbler, and an upland plover. About the moat on the outside were quite a number of least terns, a few royal terns and laughing gulls, and several spotted sandpipers. In the afternoon a trip was made from the station on Loggerhead Key to the light-house and the following were noted: 3 yellow palm warblers, 1 female redstart, a pair of marsh hawks, many barn swallows, quite a number of kingbirds, a pair of sharp-shinned hawks, 1 black-billed cuckoo, a Wilson's plover, 2 kingfishers, several male bobolinks, and a catbird.

May 3.—On an early morning walk down the center of the island from the laboratory to the light-house, and between this and the north point on the north side of the island, the following birds were noted: Many barn swallows, a somewhat lesser number of white-bellied swallows, 1 marsh hawk, 1 catbird, many yellow palm-warblers (of which I saw 5 at one time), a flock of male bobolinks, 2 kingbirds, a pine warbler, a sharp-shinned hawk, a spotted sandpiper, a kingfisher, a black-billed cuckoo, a black-throated blue warbler, several least sandpipers, 2 Wilson's plovers, a Florida yellow-throat, a pair of redstarts, several sanderlings, a semipalmated sandpiper, a water-thrush, a parula warbler, and a myrtle warbler.

May 4.—Making a trip along the central pass after breakfast I saw the following: A small flock of male bobolinks, 3 kingbirds, many barn swallows, a black-throated blue warbler, a marsh hawk, and a yellow palm warbler. Later in the day, at Fort Jefferson, I noted within its walls a pair of sharp-shinned hawks, a pair of ospreys, and several yellow palm warblers. Along the moat on the outside were spotted sandpipers, a Florida yellow-throat, least terns, and royal terns.

May 5.—On a trip from the laboratory to the light-house the following birds were noted: Barn swallows in lesser number than noted heretofore, a few white-bellied swallows (also in diminished numbers), yellow palm warblers, a redstart, a parula warbler, a water thrush, a sharp-shinned hawk, a spotted sandpiper, a kingfisher, a marsh hawk, and a goldfinch.

May 6.—On a trip from the laboratory to the light-house the following birds were noted: One catbird, 1 yellow palm warbler, a number of barn swallows, a black-poll warbler, a pair of Florida yellow-throats, a broad-winged hawk, and a green heron on the beach near the light-house.

May 7.—On the usual early morning trip from the laboratory to the light-house the following birds were seen, most of them in the trees about the light-house: One catbird, a pair of redstarts, an upland plover, a semipalmated plover, 2 brown pelicans, 10 royal terns, a black-poll warbler, a Cape May warbler, a Florida yellow-throat, several barn swallows, 2 female bobolinks, a spotted sandpiper. In passing Bird Key on our way to Key West we noted about 25 man-of-war birds among the bushes and a few laughing gulls flying about among the throng of sooty and noddy terns. The royal terns, as usual, occupied the stakes. At Marquesas Key, in the afternoon, we saw quite a number of birds, as follows: Great blue heron, egret, yellow-crowned night heron, barn swallows, osprey, snowy heron, Bahama red-winged blackbirds, black-bellied plover, black-poll warblers, mangrove cuckoo, bobolinks, least sandpipers, Florida yellow-throats. I was told some young roseate spoon-bills had been taken on this key the year before.

May 8.—At Sands Key we noted man-of-war birds and laughing gulls on the way, and on the island several hundred pairs of least terns breeding. A crippled herring gull has made the island its camping-ground. A pair of royal terns was also seen. The water-tank having a slight leak, causing a very scanty dripping, furnished quite a number of the migrating birds a drinking fountain, and here we noted a redstart, a black-poll warbler, a mourning warbler, a Florida yellow-throat, a water thrush, and a black-throated blue warbler. On the beach were seen least and semipalmated sandpipers.

Scientific Equivalents for the Common Names of Birds used in the preceding list.

Herring gull = Larus argentatus.
Laughing gull = Larus atricilla.
Royal tern = Sterna maxima.
Least tern = Sterna antillarum.
Sooty tern = Sterna fuscata.
Noddy tern = Anoüs stolidus.
Red-footed booby = Sula piscator
Florida cormorant = Phalacrocorax auritus floridanus.
Brown pelican = Pelecanus occidentalis.
Man-of-war bird = Fregata aquila.
Roseate spoonbill = Ajaja ajaja.
Ward's heron = Ardea herodias wardi.
Egret = Herodias egretta.
Snowy egret = Egretta candidissima candidissima.
Louisiana heron = Hydranassa tricolor ruficollis.
Green heron = Butorides virescens virescens.
Yellow-crowned night heron = Nyctanassa violacea.
Least sandpiper = Pisobia minutilla.
Semipalmated sandpiper = Ereunetes pusillus.
Sanderling = Calidris leucophæa.
Upland plover = Bartramia longicauda.
Spotted sandpiper = Actitis macularia.
Black-bellied plover = Squatarola squatarola.
Wilson's plover = Ochthodromus wilsonius.
Ground dove = Chæmepelia passerina terrestris.
Marsh hawk = Circus hudsonius.
Sharp-shinned hawk = Accipiter velox.
Florida red-shouldered hawk = Buteo lineatus alleni.
Broad-winged hawk = Buteo platypterus.
Pigeon hawk = Falco columbarius columbarius.
Osprey = Pandion haliaëtus carolinensis.
Mangrove cuckoo = Coccyzus minor minor.
Black-billed cuckoo = Coccyzus erythrophthalmus.
Kingfisher = Ceryle alcyon.
Red-bellied woodpecker = Centurus carolinus.
Gray kingbird ? = Tyrannus dominicensis?
Bobolink = Dolichonyx oryzivorus.
Bahama red-winged blackbird = Agelaius phœniceus bryanti.
Boat-tailed grackle = Megaquiscalus major major.
Goldfinch = Astragalinus tristis tristis.
Nonparcil = Passerina ciris.
Scarlet tanager = Piranga erythromelas.
Barn swallow = Hirundo erythrogastra.
White-bellied swallow = Iridoprocne bicolor.

Scientific Equivalents for the Common Names of Birds, etc.—Continued.

Parula warbler = Compsothlypis americana americana.
Cape May warbler = Dendroica tigrina.
Black-throated blue warbler = Dendroica cærulescens cærulescens.
Myrtle warbler = Dendroica coronata.
Black-poll warbler = Dendroica striata.
Pine warbler = Dendroica vigorsi.
Yellow palm warbler = Dendroica palmarum hypochrysea.
Water thrush = Sciurus noveboracensis noveboracensis.
Mourning warbler = Oporornis philadelphia.
Florida yellow-throat = Geothlypis trichas ignota.
Redstart = Setophaga ruticilla.
Catbird = Dumetella carolinensis.
Olive-backed thrush = Hylocichla ustulata swainsoni.

Report upon Investigations at Tortugas, by L. R. Cary.

The measurement of specimens of three species of gorgonians growing under natural conditions on the reefs about Loggerhead Key was made this season to continue a record started in 1910. On all of the reefs the number of specimens not more than two years old was found to be much greater than at any previous season since these records have been kept. When the measurements were made in 1911 very few young specimens were found, while in 1912 many year-old individuals were found, but few of the age of two years. The records for the present season show that a normal number of one and two year old individuals were present on the reefs for the first time since the almost complete destruction of small specimens by the hurricane of October 1910. The measurements and photographing of specimens of gorgonians previously cemented upon tiles were continued and new tiles, bearing individuals of different ages, were photographed and fastened with pins upon the reefs.

A series of experiments involving more than 100 individuals of *Cassiopea* was carried out to determine whether or not, other factors being constant, muscular activity has any influence upon the rapidity with which new tissue is regenerated to repair an injury. In one set of experiments one member of each pair of medusæ was rendered inactive by the removal of its marginal sense organs, which control muscular activity; while from the other member of the pair an equal amount of tissue was removed from between the sense organs, leaving the medusa active. In another set of experiments the sense organs were removed from one-half the bell-margin, while from the other half the tissue was removed from between the sense organs. A narrow strip of ectodermal tissue was removed from the subumbrella surface of the bell, thus insulating the two halves so that the one from which the sense organs had been removed remained inactive. In a third experiment a single sense organ was left upon one half of the bell margin and the two halves insulated in the manner just described. In all the experiments a circle of tissue of constant diameter was removed from the center of the disk and the amount of regeneration measured from the edges of this cut. In every instance where one half of the medusa was active and the other inactive regenerated tissue became noticeable first upon that half which was active. In the pairs which consisted of an active and an inactive individual regenerated tissue first became apparent in the active specimen. Where a single sense organ was left upon one half of the bell-margin the regeneration took place with equal rapidity from the two halves. In the later course of the experiments the amount of regeneration was about equal from the two halves, so that the point of closure in the disk of new tissue lay eccentrically, being always closer to the side which had been inactive, and from which the growth of new tissue had been slower in starting.

Individuals of both sexes of *Centrechinus setosum* with ripe sexual products were obtained in abundance during the last week in September. The eggs

average 50 micra in diameter and are very transparent, affording exceptionally favorable material for study while alive. The number of chromosomes is about 20.

Colonies of *Palythoa mammillosa* bearing apparently mature eggs were found in abundance, and in a few instances male colonies that were throwing sperm were observed among specimens kept in running-water aquaria. None of the eggs could be made to develop by artificial fertilization, nor could more than one or two atypical mitoses be brought about by using the common methods of artificial parthenogenesis. From observations extending over a period of four years and including the months of January, May, June, July, August, September, and October it appears that there is no definite breeding season for *Palythoa*, but that the sexual products are thrown in small numbers at any season of the year whenever they are mature.

Experiments with the Eggs of Toxopneustes, by A. J. Goldfarb.

During the summer of 1912, I succeeded in grafting the fertilized eggs of *Toxopneustes variegatus*, by a new method which had several advantages over the methods used by myself and by Driesch and Herbst in previous experiments of this nature. The method consisted essentially in subjecting the fertilized eggs to the action of a solution made of approximately 80 parts of sea-water and 20 parts of an isotonic or slightly hypotonic NaCl solution. Relatively large numbers of the eggs were agglutinated and many subsequently fused at varying stages in their development, and gave rise to types of fused larvæ which will be described in detail in Publication 183 of the Carnegie Institution of Washington. It was my plan to determine whether the eggs of other species of echinoderms could be made to fuse together and whether the same treatment would be efficacious. It was furthermore planned to fuse the eggs of different species together by the same method, so that a graft hybrid might be produced, and the antagonistic reactions of the internal organs of each larva might the more readily be studied.

Considerable difficulty was experienced in obtaining sexually mature *Toxopneustes* at the Dry Tortugas. At Boca Grande some were obtained and experimented upon. The resulting fused larvæ corroborated the findings of the preceding summer and afforded materials for the study of the individual histories of such fusions, particularly of the skeletal changes. No other echinoderms were found near the Tortugas sufficiently ripe to test the possibility of fusing different species. At Boca Grande some eggs of *Hipponoë* were obtained, artifically fertilized, placed in the NaCl solutions and gave rise to agglutinated and fused larvæ, of the same general types as those found among the *Toxopneustes.* Not enough eggs, however, were procured to make the grafting of two species possible.

The same NaCl method was later used at Woods Hole, with the sea-urchin *Arbacia punctulata*, and an extraordinarily large number of fused larvæ were produced. There can be no doubt that the NaCl method was effective in at least three species of sea-urchin eggs, and it is highly probable, in the light of the recent work of de Haan, that different species of eggs can be made to fuse, and enable the experimenter to observe the interesting internal changes of the developing organs involved in such graft hybrids.

Summary of Work Done on the Fishes of Tortugas, by E. W. Gudger, State Normal College, Greensboro, North Carolina.

During the four weeks spent at Tortugas in 1913 I continued the work on the fish fauna begun in 1912. Among elasmobranchs I collected data on the breeding-habits of the nurse shark, *Ginglymostoma cirrotum,* spending

five days during the middle of June at Boca Grande Cay for that purpose. Here the fish are to be found in large numbers, 23 being counted at one time, 33 at another. They come out of the deeper water to bask in the sunshine and play in the shallows on the south side of the island, and are fearless of man. Several times I drifted over groups of two to five of them, they making no movement until the keel of the boat touched their dorsals. As the breeding-season was only just beginning, it was impossible to collect any material for the embryology of the fish.

At Tortugas and at Key West I was fortunate in obtaining specimens of *Hypoprion brevirostris* and of *Galeocerdo tigrinus* (the tiger shark). The data obtained from these, in addition to that secured last season, will make it possible to write careful descriptions of these two sharks. This is desirable, since the descriptions now available are very brief and imperfect. The largest tiger shark was 11½ feet long and was estimated to weigh from 600 to 800 pounds.

In addition to the above, a specimen of the dusky shark (*Carcharhinus obscurus*) 8 feet long was captured at Key West. It and several others of these sharks were females, but unfortunately none of them carried embryos. Thus the opportunity was lost of settling the interesting question of the method of gestation in these sharks.

Further observations were made on the structures and habits of the sting-ray (*Dasyatis hastata*), but no embryos were obtained. Four specimens of the beautiful spotted eagle-ray, *Aëtobatus narinari*, were obtained at Key West, and sufficient data obtained to finish my history of this fish. This paper will appear in volume 6 of Papers from the Tortugas Laboratory (Carn. Inst. Wash. Pub. 183).

Considerable numbers of teleostean fishes were collected and dissected, and careful notes made of their habits and structures. There is now at hand a considerable volume of data on the natural history of these fishes. During this season several were taken which are new to the fauna of the Tortugas, and at least one, *Diplodus sargus*, which (so far as I know) has not before been recorded from the waters of the United States.

Report of Investigation of Color of Gulf-weed Fauna and of Reef Fishes, by W. H. Longley, Goucher College, Baltimore.

During the month of June, I continued the investigation of the ecological relations of the gulf-weed fauna begun two years before. The point toward which inquiry was particularly directed concerns the significance of the color combination which appears so commonly upon the animals occurring in the floating *Sargassum*. Not less than 12 species (4 fishes, 2 crabs, 2 shrimps, 3 gastropods, and a planarian) are marked with the gulf-weed colors, chiefly shades of brown and yellow. Moreover, some of these animals possess external organs whose likeness to the leaf-like divisions of the plant-body seems to be thoroughly objective. Since these species appear to be confined to the floating algæ, it is strongly suggested that their uniformity in color as well as their convergence in structure toward that of the plant is in some essential way related with the lack of variety, the comparative simplicity, or poverty, of the environment in color and form elements. We seem, therefore, to have here an impressive series of instances of "concealing coloration" coupled with structural modifications tending likewise to protect their possessors by rendering them invisible in their normal environment.

As an example of a group of animals in which some principle other than that of protective coloration has been said to be operative, a preliminary study of the colors, color-patterns, and color-changes of 30 species of reef

fishes has been made. These do not include even all the common forms and comparatively little is known as yet concerning the conditions under which they live, but a number of facts of considerable suggestive value have been established.

(1) Obliterative shading is obvious in all those species whose bodies are cylindrical or fusiform, but is difficult to detect in angel fish and others laterally so compressed that without evident counter-shading they seem flat when seen in profile. Since it is difficult to avoid the conclusion that this shading is the fundamental factor in concealing coloration, its very common or universal occurrence among the reef fishes proves a serious obstacle in the way of any hypothesis which assigns warning value to their colors or color-patterns. It renders equally improbable the idea that color and color-patterns represent the result of some unknown internal activity, which has produced an immunity type of coloration, because the reef fishes, on account of habits or activity, are not subject to successful attacks of piscivorous enemies.

(2) Among the 30 species studied, there is no case in which any evident reduction of defensive characters—scales, spines, teeth, etc.—is associated with conspicuous color or combination of colors, as might be expected upon the immunity hypothesis. Neither is there any consistent relation between the presence of remarkably developed spines or teeth and types of color or pattern which seem to be of a warning nature. The spotted moray, one of the most voracious and pugnacious of the reef fishes, is mottled brown and yellow. One of the surgeon fishes (*Teuthis hepatus*), armed with a lancet upon either side of the caudal peduncle, may appear in a blue-black phase or yellow-green, or may be as gray and inconspicuous as the gray snappers with which it may frequently be seen swimming above the gray sand.

(3) Upon the reef as a whole, browns and gray are the commonest colors. However, the reefs and reef-flats are not in all parts equally frequented by fish, so that relative frequency of colors can not be gaged simply by determining the areas covered by gray sand, brown algæ, etc. Upon those parts of the Loggerhead reefs where fish are most abundant, the heads of *Porites astrœoides*, or rather the symbiotic algæ associated with them, contribute a very conspicuous yellow element to the environment in which the fish live.

A rather rough analysis of the colors found upon the 30 species examined has been made and the relative frequency in which the different colors occur is as follows: Yellow, 19 times; brown and gray, 16 times each; blue, 8 times; red and green, 5 times each; and black, 3 times. I do not for a moment advance the idea that colors occur upon the fish in the same proportion as that in which they appear upon the reef, but suggest that the facts above noted indicate a correspondence between reef and fish colors which agrees more closely with the case of the *Sargassum* species than might have been anticipated upon the hypothesis of immunity or of warning color.

Report upon Investigation of the Dimorphic Spermatozoa of Strombus gigas, by E. E. Reinke, Princeton University.

The object of this investigation was to determine as far as possible what physiological relation exists between the eupyrene (typical) and the apyrene (atypical) spermatozoa of *Strombus*. Twenty-five females which had copulated were carefully dissected and the contents of the vagina, the uterus, and the bursa seminalis were examined microscopically in order to ascertain the fate of the two kinds of spermatozoa. In brief, it was conclusively

found that the eupyrene spermatozoa are separated from the apyrene and are stored in the modified portion of the wall of the uterus, which has elsewhere been described by the writer as the seminal receptacle. The apyrenes, on the other hand, undergo degenerative changes and, together with some eupyrenes which do not reach the uterus, are inclosed in a capsule secreted from the walls of the bursa seminalis. Eventually the whole capsulated mass is thrown off. The presence of such a mass in the bursa seminalis and of an ejaculate in the vagina was taken, in those cases in which they were both observed, as an indication that copulation had taken place at least twice. Oviposition had not as yet commenced.

A start was also made upon a series of experiments to discover the physiological reactions of the two kinds of spermatozoa. Cultures in various media, sterilized sea-water, lymph, fluid from the bursa seminalis diluted with sea-water, and fluid from the albumen gland of the male also diluted with sea-water, were grown in live cells. Sterilized sea-water was found to be the most satisfactory medium. In it cultures of both kinds of spermatozoa could be kept alive for from 60 to 72 hours when infection did not occur. When kept alone the eupyrenes lived for a shorter time—49 hours in one instance. In all cases the movements of the apyrene spermatozoa were carefully studied.

A few cultures were started, in each of which was placed a small piece of decaying tissue. In these cases the reaction of the eupyrene spermatozoa was slow but quite positive; they moved away from the CO_2 generated by the tissue. The reaction of the apyrene spermatozoa was less clear; in one instance there was a distinct grouping around the tissue, in the other cultures they remained unstimulated. In all cases those eupyrene which remained in the area left clear of eupyrene spermatozoa were broken down and disintegrated to a greater or less degree after 12 hours.

Report of A. L. Treadwell.

My work at Tortugas in 1913 has been mainly a continuation of systematic work begun in earlier years, and considerable progress has now been made in the preparation of a monograph of West Indian Eunicidæ. The closing of the laboratory before the time of sex maturity of any of these annelids prevented some proposed study of their embryology. An attempt was made at producing experimentally a form of collateral budding which has been described in several species of the genus *Trypanosyllis*, but without success. The results, however, indicated a possible method of controlling the sex-rhythms of this animal, and it is hoped that these experiments may be continued later.

In connection with the systematic research, I wish to record my appreciation of the skilful work done by Mr. S. C. Ball in the preparation of watercolor paintings of the Eunicidæ.

A Study of the Homing Instinct in the Noddy and the Sooty Tern which Nest upon Bird Key, Tortugas, by John B. Watson and K. S. Lashley.

On May 15, 1913, 12 noddies (*Anous stolidus*) and 12 sooty terns (*Sterna fuliginosa*) were captured, marked by painting their feathers, and sent to Key West, where they remained until May 19, when they were placed on board the steamer *San Marcos* and taken to Galveston, Texas, in charge of Mr. Lashley.

These birds were kept in the hold of the vessel, forcibly fed upon small clupeoid fishes, and remained in good condition until released. Of the 24 birds which were released 13 returned to Bird Key, 3 of them returning from Galveston Harbor, 785 statute miles from Bird Key, while 2 others, which were released at night, in a rain, 135 miles from the nearest land (Galveston) and 650 miles from Bird Key, returned to their nesting places on Bird Key. Also 8 out of 10 birds which were released in the morning near the middle of the Gulf of Mexico, 515 miles from Bird Key, returned.

The following table gives a summary account of the experiments:

Day and hour when birds were released.	Number released.	Kind of birds.	Distance in statute miles from Bird Key.	Number of birds that returned to Bird Key.	Time taken in returning to Bird Key.
May 20, $8^h\ 45^m$ p.m...	2	Both noddies......	348	0..................	
May 21, 8 a.m.......	10	6 sooties, 4 noddies.	515	8 (3 noddies, 5 sooties)	From 3 days 22 hours to 7 days 21 hours.
May 21, 7 p.m.......	2	2 noddies..........	650	2..................	One in 11 days 13 hours, the other in 17 days 2 hours.
May 23, $5^h\ 30^m$ a.m...	10	4 noddies, 6 sooties.	785	3 (1 noddy, 2 sooties)	From 6 days 2 hours, to 11 days 23.5 hours.

Weather conditions during the period of the experiment were favorable, the sea being either calm or the wind being mainly from the west or northwest.

In another experiment, 12 noddies were captured on May 5 and sent to Key West, and on May 8 were put on board the steamer *Alamo* and confined in the hold of the vessel, and all 12 birds were released at the entrance of Mobile May on May 13 at $5^h\ 55^m$ a. m. Only one of these birds returned to Bird Key, this one taking 7 days and 1 hour to accomplish the journey. The weather conditions were unfavorable, there being heavy southerly and southeasterly winds.

The Effect of the Amount and Frequency of Practice in Learning Archery, by John B. Watson and K. S. Lashley.

These experiments upon learning in the human being are to be continued for several years. During the past season we obtained the learning curves of eight individuals; four of the eight subjects were scientific men, while the other four were chosen from the force attached to the laboratory.

In this preliminary work each man shot twelve 28-inch arrows from a 44-pound bow at a 48-inch target covered with white canvas. In the center of the target a solid black circle, 10 inches in diameter, was painted (to take the place of the gold). The range was 40 yards.

We have data not yet completed upon the initial accuracy of men not trained in the use of the long bow, upon the relative rapidity of learning of the individuals and of the two groups of men; and upon the course of learning (*i. e.*, whether the learning curve is continuous or shows "resting" places or "plateaux").

Further work will undertake to show the effects upon different groups of individuals (of like initial scores) of different amounts and frequency of practice. It is planned to work five groups. The first group to shoot 5 arrows per day, the second 10, the third 20, the fourth 40, and the fifth 80.

Since in all probability the learning curves of these groups will show very different forms, it is planned to allow the group shooting 80 arrows per day to shoot 5 times with the rifle; and the group shooting 5 arrows per day to shoot 80 times per day with the rifle, etc. In this way individual variations may be eliminated and the pure effects of frequency and amount of practice arrived at.

Nesting Instincts of Noddy and Sooty Terns, by K. S. Lashley, Johns Hopkins University.

The question of proximate orientation of the noddy and sooty terns was studied. Watson, 1908,* carried out some experiments which indicated that the recognition of the nest-locality by these birds is extremely accurate, but he did not determine exactly the sensory data involved in the adjustment. The work of this season was directed toward the solution of this problem and enough data have been collected to show that the adjustment is almost wholly visual, although the reaction is very complicated.

In connection with proximate orientation, the recognition of the young was studied. The noddies gave no evidence that the young are distinguished one from another, or even from the young of the sooties. The sooties, whose nesting habits made such a recognition imperative, do not at first distinguish their own from the young of other sooties. About 8 to 10 days after the eggs hatch, however, they begin to recognize their own young, at first imperfectly, later more surely. There is evidence that the recognition is based rather upon the behavior than the appearance of the young birds.

It was found possible to modify the behavior of the birds by exchanging older for younger chicks, chicks for eggs, etc., and to change the duration of the laying and incubation periods to a considerable extent.

The Reef Corals of Southern Florida, by Thomas Wayland Vaughan, U. S. Geological Survey.

During May and June, while at the Tortugas, the measurements and records of coral colonies under observation to ascertain the rate of growth of the different species were continued. The studies of growth-rate have made satisfactory progress, as a number of colonies known to be three years old are steadily growing; other colonies, planted or naturally attached, have now been under observation for periods ranging from two to five years. Some naturally attached colonies of branching species of *Porites* have begun to disintegrate because of boring organisms perforating their bases. The growth records, which are too numerous for even a résumé of them to be given in this report, are kept in tabulated form and will later be published. In addition to the studies mentioned considerable advance was made in platting the position of reefs, coral patches, and more isolated colonies on the maps of the area.

The assembling of data bearing on the ecology of the species of corals living in the waters of southern Florida has been continued. Dr. H. F. Moore, of the Bureau of Fisheries, has furnished complete tables of temperature records based on readings at the principal light-houses along the line of the reefs. These records give for each station the average temperature in periods of 10 days and the maximum and minimum in the series of years over which the 10-day periods extend. As Dr. Mayer has conducted experiments to ascertain the upper and lower vital temperature limits of the common shoal-water corals of Florida, the temperature relations of these

*Watson, J. B., 1908, The Behavior of Noddy and Sooty Terns. Papers from the Tortugas Laboratory, vol. II, Carn. Inst. Wash. Pub. 103.

corals need only two additional lines of inquiry in order to be adequately known. One of these is to obtain more accurate information on the temperature gradient with increasing depth of water, a subject on which some data are available but have not been tabulated. The other line of inquiry is to ascertain the upper and lower limits of temperature at which corals will take food.

A few samples of water were collected in 1912 for salinity determination, and, by an arrangement with Mr. George C. Short, samples of water were collected in Fort Jefferson moat during and after heavy rains in January and February 1913. The latter samples are intended to indicate the amount of dilution to which the water in the moat is subject. Through an arrangement effected between the Laboratory of Marine Biology and the U. S. Geological Survey, Mr. R. B. Dole, of the latter organization, undertook during June the examination of a series of water samples collected at the Tortugas. He determined the salinity of the samples collected by Mr. Short and of a set of samples collected twice daily, at ebbing and flowing tide, for nearly a lunar period, in Southwest Channel off the southern end of White Shoal. Other samples were also examined.

The following data furnished by Mr. Dole are to be considered in this connection:

*Salinity of Tortugas waters, as determined by R. B. Dole.**

Locality.	Time.	Chlorine.	Salinity.
		‰	‰
Fort Jefferson Moat	During rain, January 27, 1913	19.61	35.43
Do	After rain, same date	19.60	35.41
Do	During rain, February 27, 1913	19.83	35.82
Do	After rain, same date	17.79	32.14
Moat at sally port, Fort Jefferson	May 25, 1913	19.67	35.53
Do	June 14, 1913	19.83	35.82
Inside moat floodgate, Fort Jefferson	May 25, 1913	19.82	35.80
Do	June 14, 1913	19.95	36.04
Southwest Channel, average of 29 ebb-tide samples in May and June 1913		19.932	36.01
Southwest Channel, average of 23 flood-tide samples		19.936	36.01

*A more comprehensive statement is made by Mr. Dole in his article "Some chemical characteristics of sea-water at Tortugas, Florida," Carn. Inst. Wash. Pub. No. 182.

The water specimens collected in July 1912 were titrated, through the kind offices of Mr. Drew, by Mr. D. J. Matthews, at the Plymouth, England, marine laboratory, and gave the following results:

Salinity of Tortugas waters, as determined by D. J. Matthews.

Locality.	Chlorine.	Salinity.
	‰	‰
Northwest face of Loggerhead Key	19.95	36.04
Channel east of Brilliant Shoal	19.99	36.11
Channel, Fort Jefferson wharf	19.99	36.11
Fort Jefferson moat	20.09	36.29

More information on salinity along the line of the reefs is greatly desired, and it is hoped this may be procured. Experimental investigation of the degrees of salinity, the maximum and minimum which the different species of corals will endure, remains to be made.

Besides his determinations of salinity, Mr. Dole also investigated the amount of dissolved oxygen in the Tortugas waters. Though he does not report his results in detail, he says that the sea-water is practically saturated, a state indicating that there is plenty to oxidize decomposing matter without danger of anaerobic conditions.

As the program for studying the Florida shoal-water corals is now approaching its conclusion, a statement of additional desiderata will be made, as follows: (1) to continue the growth observations for at least two more seasons; (2) to complete the inspection of the Tortugas area for the location of the reefs, coral patches, etc.; (3) to dredge from shoal water to a depth of 50 fathoms, take temperature readings, and collect bottom samples; (4) to conduct experiments on the upper and lower temperature limits at which the different species of shoal-water corals will take food; (5) to conduct experiments on the minimum and maximum salinity (amount of dilution and concentration of sea-water) corals will endure; (6) to conduct additional experiments on the exclusion of light from shoal-water corals; and (7) to ascertain the length of the free-swimming larval stage of several other species. Although this list is rather long, the fulfillment of the requirements of each item is simple.

Investigations of the Geology and Geologic Processes of the Reef Tracts and Adjacent Areas in the Bahamas and Florida, by T. W. Vaughan.

During the office season of 1912–13 much laboratory work was done on the bottom specimens and lithologic samples obtained in Florida and the Bahamas during the field season of 1912. I devoted considerable time to studying the material and was enabled to announce that—

"The empirical facts in the process of the formation of the Floridian and Bahaman oolites are demonstrated. They are as follows: (1) Denitrifying bacteria are very active in the shoal waters of both regions and are precipitating enormous quantities of calcium carbonate which is largely aragonite; (2) this chemically precipitated calcium carbonate may form spherulites which by accretion may become oolite grains of the usual size, or it may accumulate around a variety of nuclei to build such grains."*

The study of this material is still in progress, and the report on it is not yet complete. In order that it might receive the most thorough treatment possible the assistance of a number of specialists was obtained. Dr. F. E. Wright, of the Geophysical Laboratory, examined some of the bottom samples; Dr. J. A. Cushman, of the U. S. Geological Survey, has furnished lists of the foraminifera; the chemical laboratory of the U. S. Geological Survey has had a series of chemical analyses of bottom samples and specimens of oolite made by one of its staff, Mr. W. C. Wheeler; physical analyses of a set of samples are being made by Mr. E. W. Shaw, of the U. S. Geological Survey, in association with the Bureau of Soils of the Department of Agriculture; and Dr. Paul Bartsch, of the U. S. National Museum, will report on the fossil mollusca of the oolites. Dr. Bartsch is also preparing a special report on boring organisms that cause the disintegration of coral skeletons.

In addition to that regarding the formation of oolite, a few other general statements as to the shoal-water calcareous muds of the Florida key region and of the Bahamas may be made. Except in the region of Biscayne Bay, the chemical analyses show a high percentage of calcium carbonate, over 90 per cent. There is not only no terrigenous material in the muds obtained in the

*Jour. Wash. Acad. Sci., vol. 3, No. 10, p. 303, 1913.

Bahamas, but there is practically none in the mud along the Florida keys a short distance from the mainland. There is in this region an instance of an extensive deposit of an almost pure limestone forming near the shore of a land-mass which is of low relief and across which no large streams bear detritus. The investigations also show that in areas in which oolitic limestone is being formed testaceous as well as most other organisms are scarce, in this respect corresponding to the geologically older oolites. The chemical analyses show the presence of a very little phosphate, a fact which may be correlated with the general paucity of organisms. Another fact of interest is the small percentage of magnesium in both the bottom muds and in the Pleistocene oolites, the range of magnesium oxide (so expressed in the analyses) being from a trace to 2.14 per cent. In one instance (shore material from the west side of Andros Island) there is 5.82 per cent of magnesium oxide, the highest percentage recorded.

During the field season of 1913 the study of the bottom deposits of the area and of geologic processes in general for the purpose of obtaining a proper basis for interpreting the geologic history of the area was continued. The bottom deposits of Marquesas and Tortugas lagoons received special attention. Among the geologic processes investigated were the effect of waves and currents in building and shaping banks, the relations of the banks and keys of the Marquesas and Tortugas to waves and currents, cutting by waves and currents, the building of terraces by waves; a special investigation of submarine solution by flowing sea-water was undertaken in association with Mr. R. B. Dole, of the U. S. Geological Survey. As in each instance positive results were obtained, and as the principal factors in the formation of Marquesas and Tortugas atolls and their inclosed lagoons now seem clear, although some details still require elucidation, a brief account of the investigations and the conclusions based on them has been written and will appear in Publication No. 182 of this Institution. This account is followed by a sketch of the geologic history of the entire Florida reef tract, and comparisons are made with Andros Island, Bahamas, Cuba, and some of the tropical Pacific areas.

A report prepared by Mr. Dole, giving a summary statement of the results of his examination of the Tortugas water for salinity and carbon dioxide, will appear in Publication No. 182 of this Institution, now going through press.

DEPARTMENT OF MERIDIAN ASTROMETRY.*

BENJAMIN BOSS, ACTING DIRECTOR.

The Department of Meridian Astrometry has suffered a severe loss during the period covered by this report (September 1912 to September 1913), through the death of its Director, Professor Lewis Boss, on October 5, 1912. As the President of the Carnegie Institution of Washington has incorporated a biography of Professor Boss in Year Book No. 11, page 8, it will be sufficient here to say that he foresaw a possible breakdown in time to prepare for it, so that the work of the Department has suffered no check.

INVESTIGATIONS.

During the past year, aside from the prosecution of the general scheme, considerable attention has been given to investigations growing out of the published results or accumulated material.

Professor Lewis Boss, in the Astronomical Journal, Nos. 623–624, placed the apex of solar motion, as derived from the G or solar type stars, at some distance from the apices derived from the solution of other types. Professor Campbell, in the Lick Observatory Bulletin No. 196, derived a smaller value for solar motion from his treatment of G-type stars than the values obtained from his solution of other types. The two phenomena seemed to indicate some real peculiarity in the motions of the G-type stars.

After hypothetically freeing the proper-motions from the effects of solar motion, a solution was made to determine any residual drift motion, the result indicating a preference of motion of the G-type stars toward a point at right ascension = 272°.7, declination = 5°.2, in the ratio of 3 to 2. This would seem to indicate that the G-type stars as a class are drifting toward what is commonly termed the antivertex of preferential motion, or the apex of drift II, according to Kapteyn's convention. The solution excluded proper-motions exceeding 20 seconds of arc per century. Their inclusion would tend to reduce the ratio above mentioned. This phenomenon, if further confirmed by the inclusion of additional G-type stars, will bear an important part in the derivation of solar motion.

Another phenomenon which has been noted, and will receive further attention, is the peculiar distribution of the apices of solar motion as derived from the solution of the other types.

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*Address Dudley Observatory, Albany, N. Y. Grant No. 864. $25,180 for investigations during 1913. (For previous reports see Year Books Nos. 2–11.)

In the following table the first column indicates the spectral type according to the Harvard classification. Column 2, headed R. A., gives the right ascension, and column 3, headed D, gives the declination of the solar apex as derived from the separate solutions by type. The last column, headed V, indicates the velocity of the sun's motion as derived by Campbell for each separate type.

Type.	R. A.	D.	V.
	°	°	
K	275.4	+40.3	−21.2
M	273.6	+38.8	−22.6
B	274.4	+34.9	−20.7
All	270.5	+34.3	−19.5
A	270.0	+28.3	−16.8
F	265.9	+28.7	−15.8

As can readily be seen, the results for the K and M types and those for the A and F types are closely similar, but the two groups are distinct. In other words, there seems to be some peculiarity in the systematic motions of the early type stars as represented by the A and F types, quite at variance with the systematic motions of the later types, as represented by the K and M types. The B-type stars, though an early type, have such small real velocities that any systematic peculiarity in their motions would have but little effect upon the determination of solar motion. It is, therefore, not surprising to find the solar motion as derived from this type closely approximating the general solution for all types.

There may be some significance attachable to the fact that the apices as given in the table are very nearly distributed along a parallel of approximately 21° galactic latitude.

The G-type stars, as previously stated, give an anomalous result.

A number of star groups have been collected where there seems to be a possible community of motion, but where the proper-motions are so small as to render it impossible to determine a convergent point by their means. These groups have therefore been recommended to the spectroscopist for attention.

In the case of a number of these groups a mean value for the proper-motion of each group has been taken, and their directions of motion plotted with a view toward uncovering any possible systematic motion among stars of small proper-motion. As a result, four groups have been found with a common intersection at about right ascension $= 4^h\ 45^m$ and declination $= -15°$. While the effect may be the result of chance, the rather sharp convergence would seem to indicate causal connection.

Another investigation dealing with stars of large proper-motion, 20 seconds per century or more, is being pushed. This subject has

already been dealt with by Dyson on the basis of the two-stream hypothesis, and by Beljawsky using the ellipsoidal hypothesis. Both of these methods involve the consideration of position-angle alone. Therefore, the present investigation, which employs both position-angle and proper-motion, should be of interest.

A diagram has been prepared on a Mercator projection, on which the paths of all the stars of large proper-motion in the Preliminary General Catalogue have been plotted, 20 seconds per century being taken as the limiting proper-motion. Although it might have been predicted *a priori* that there would be a strong convergence of these paths in the region 6^h right ascension, 0° declination, the actual convergence is startlingly portrayed. This would indicate that the true paths of the stars of large proper-motion through space are in the main very nearly parallel. This result might independently be obtained if we consider the ellipsoidal hypothesis; for the method of selection of the proper-motions would cut out nearly all the proper-motions with the exception of those directed toward the apices of the ellipse.

We have, then, the means of determining hypothetical parallaxes for all those stars, selected as outlined, for which radial velocities are given, on the hypothesis that the paths of these stars through space are absolutely parallel, the direction of their vanishing-point being taken as the vertex of preferential motion. In a majority of cases the computed parallax should very closely approximate the true parallax, since the deviation of the paths of the stars chosen from true parallelism will seldom be sufficient to seriously affect the computed parallax.

The charted paths of the apparent motions show several sharp convergents, one being almost exactly that of the Taurus group. These indicated convergents will be investigated for possible group motion.

COOPERATION.

It is pleasing to record that the growing spirit of cooperation so manifest among astronomers of to-day has led Professor George C. Comstock to volunteer the aid of the Washburn Observatory in the observation and reduction of a list of about 3,200 stars of $6^{\mathrm{M}}.9$ or brighter, included within a zone extending from +30° to −21°.5 declination. These stars comprise all the miscellaneous stars on our observing list lying between the given limits and within the chosen limit of magnitude, the term "miscellaneous" referring to those stars whose positions are less determinate than the positions of the stars in the Preliminary General Catalogue. These stars will be observed differentially, the system of the Preliminary General Catalogue serving as a basis. They will also be observed at Albany. The two independent determinations of the positions of these stars at approximately the same epoch will lend more weight to the determination of their positions and proper-motions than could be

expected to result from a larger number of observations taken under the same conditions at one observatory. A supplementary list of 2,600 stars of $7^{M}.0$ to $7^{M}.9$, lying within the same limits of declination, has been supplied to Professor Comstock. The stars of this list will be observed at Madison as far as practicable.

OBSERVATIONS.

During the past year 12,405 observations have been taken with the meridian-circle telescope. These have been distributed among the observers as follows: B. Boss 3,283, H. Raymond 339, A. J. Roy 4,113, and W. B. Varnum 4,670. As usual, four microscopes have been recorded at each setting in zenith distance. Indicating the circle nearest the clamp by A, that opposite the clamp by B, the readings have been distributed Cl E and Cl W as follows: AE 3,184, BE 3,032, AW 3,961, BW 2,228. The distribution among the circle-readers follows: S. B. Grant 5,179, A. R. Guy 782, H. Henderson 292, H. Jenkins 1,645, and H. Raymond 4,499. The plan of observation has been the same as in previous years.

The flooding of the Hudson River Valley in March, because of its interference with the lighting system of Albany, caused the loss of some observing nights, and in a part of April and May still more time was lost during an effort to seal the Riefler clock.

REDUCTION OF OBSERVATIONS.

The reduction of current transits to the mean wire have been kept nearly up to date and checked, and the wire intervals for each observer drawn off. The material for magnitude equation is prepared currently in ready form for final evaluation. The apparent place reductions have also been duplicated nearly to date.

In working up the contacts of the micrometer wire with the middle wire Mr. Roy noted a distinct variation dependent upon temperature. By adopting a term $34^{r}.0104—0^{r}.00033\ (T-0°)$ the observed values were fitted very closely, with a probable error of $\pm 0^{r}.0017$ for a single setting. The difference between day and night readings, $-0^{r}.0014$, though about five times the probable error of the determination, has been neglected.

The effect of the screen used in reducing the magnitudes of bright stars to approximately a uniform magnitude was found to be $3^{M}.2$. Although the same screen was employed in the San Luis observations its effect at that station was $3^{M}.8$. The effect would appear to be real.

Since the last report the definitive azimuths for the San Luis observations have been computed and adopted. The accompanying table gives the resulting mean readings of the mire-mark for each month arranged in 6-hour groups according to mean time. The column at the extreme right represents the straight mean of the

preceding four columns, and the bottom row of the table gives the mean results of 6-hour divisions for the whole period of observation. It can readily be seen that the motion of the mire was slight, and such motion as is indicated does not appear to be seasonal in character. The mean of all the 6-hour groups might indicate a slight diurnal variation, but the probable errors of the means so far exceed the variations that we must conclude that the mire-mark was fixed as far as diurnal changes are concerned.

Monthly Mean Readings of Mire, San Luis.

	P. M.		A. M.		Means.
	0^h to 6^h.	6^h to 12^h.	0^h to 6^h.	6^h to 12^h.	
1909.					
April	$-^s.961$	$-^s.891$	$-^s.883$	$-^s.890$	$-^s.906$
May	−.766	−.838	−.744	−.782	−.782
June	−.876	−.858	−.818	−.856	−.852
July	−.776	−.777	−.778	−.778	−.777
August	−.848	−.864	−.842	−.826	−.845
September	−.885	−.897	−.883	−.872	−.884
October	−.846	−.836	−.802	−.818	−.826
November	−.793	−.800	−.790	−.812	−.799
December	−.840	−.815	−.787	−.790	−.808
1910.					
January	−.797	−.775	−.767	−.763	−.776
February	−.735	−.747	−.736	−.707	−.731
March	−.774	−.766	−.769	−.782	−.773
April	−.704	−.718	−.715	−.727	−.716
May	−.692	−.687	−.730	−.708	−.704
June	−.740	−.733	−.743	−.745	−.740
July	......	−.708	−.726	−.705	−.713
August	−.712	−.732	−.720	−.777	−.735
September	−.783	−.768	−.757	−.777	−.771
October	−.794	−.800	−.812	−.786	−.798
November	−.824	−.802	−.795	......	−.807
December	−.858	−.798	−.771	−.894	−.828
1911.					
January	−.839	−.832	−.748	......	−.806
Means	−.800	−.788	−.772	−.790	−.788

The preliminary clock corrections as given in the last report resulted in a systematic error dependent upon right ascension of

$$-0^s.0084 \sin \alpha + 0^s.0087 \cos \alpha$$

and the effect night minus day for the various observers:

Observer.	N—D.
R. H. Tucker	$+^s.010$
A. J. Roy	−.007
W. B. Varnum	−.016

The signs of the first two quantities N − D were erroneously interchanged in the last report.

The above corrections were applied, leaving residuals consisting of accidental errors and effects of barometer and thermometer upon the clock-rate. Consequently an attempt was made to test the dependence of the rate upon the mass of the air. Unfortunately the Riefler clock employed in San Luis was not sealed, nor were any records of temperature kept in the clock-room, which was subject to considerable changes in temperature. As the changes in the clock-room and in the observing-room would necessarily differ, the attempt to directly measure the dependence of the clock-rate upon the mass of the air proved a failure.

It therefore became necessary to devise some other means for the elimination of such a term. It is natural to suppose that the diurnal variation of temperature, acting upon a more or less constant air-pressure, would in the mean result introduce a diurnal variation in the clock-rate dependent upon the mean time. Under such an assumption we would also expect that in the long run the corrections due to such a factor would be approximately equal and of opposite sign 12 hours apart, and consequently the methods employed in the preliminary determination of clock correction should eliminate this term. That is, by the method employed we should expect to derive clock corrections free from the effects dependent upon right ascension ($\Delta\alpha_a$) and free from the diurnal term, but containing the term night minus day N − D, the constant error dependent upon the illumination of the sky. For the first approximation the latter term was neglected.

Applying the resulting clock corrections, the residual error would include the terms $\Delta\alpha_a$, N − D, and the diurnal correction. Solving for $\Delta\alpha_a$ and N − D, there would remain accidental errors and the diurnal term. As the effect N—D is generally considered to be a constant term, but as in reality the change in the illumination of the sky is gradual, there should be a small residual term dependent upon this effect.

Consequently, after applying the corrections already evaluated, the residuals were collected according to mean solar time, hourly means taken, and curves drawn. It was considered advisable to draw off the results according to seasons, both for the purpose of testing any variations in the diurnal rate due to seasonal changes and to demonstrate that the residuals thus arranged bear no resemblance to the $\Delta\alpha_a$ term, which was supposed to have been completely taken out. In the following table the diurnal term as determined by seasons bears no apparent trace of a residual $\Delta\alpha_a$ term. The variation is similar in each case and strictly according to mean time. There also seems to be a certain degree of similarity between the spring and fall terms, and between the summer and winter terms. Some

portions of the curve were quite indeterminate because of the relatively small amount of material, but the better determined part served as a guide toward filling out such regions. Since the curve shows tendencies toward a sine cosine effect, a computed curve is given under the heading Comp. While the computed curve gives a fair representation of the observations, there seem to be systematic corrections to the computed values, indicating a real effect. Therefore the curves representing the observations were adopted.

	Diurnal term.									
	Mar., Apr., May		June, July, Aug.		Sept., Oct., Nov.		Dec., Jan., Feb.		Mean.	
	Curve.	Comp.	Curve.	Comp.	Curve.	Comp.	Curve.	Comp.	Curve.	Comp.
h										
0	+^{s}.004	+ 5	+^{s}.018	+15	+^{s}.012	+12	+^{s}.028	+29	+^{s}.016	+15
1	+ 6	+ 7	+ 25	+19	+ 13	+14	+ 31	+34	+ 19	+18
2	+ 8	+ 9	+ 30	+21	+ 14	+16	+ 34	+36	+ 22	+21
3	+ 10	+10	+ 32	+22	+ 16	+17	+ 39	+37	+ 24	+22
4	+ 14	+10	+ 27	+22	+ 18	+16	+ 44	+36	+ 26	+21
5	+ 14	+10	+ 13	+20	+ 19	+15	+ 37	+32	+ 21	+20
6	+ 10	+10	+ 6	+17	+ 19	+13	+ 19	+27	+ 14	+17
7	+ 4	+ 9	+ 13	+14	+ 12	+10	+ 5	+20	+ 8	+13
8	+ 4	+ 7	+ 8	+ 9	+ 2	+ 6	+ 4	+13	+ 4	+ 9
9	0	+ 5	− 2	+ 4	− 10	+ 2	+ 7	+ 5	− 1	+ 4
10	− 3	+ 3	− 6	− 1	− 7	− 2	+ 3	− 3	− 3	0
11	+ 5	+ 1	− 6	− 6	− 3	− 5	− 4	−10	− 2	− 5
12	+ 8	− 1	− 7	−10	− 4	− 9	− 11	−17	− 4	− 9
13	+ 5	− 3	− 8	−13	− 6	−11	− 16	−21	− 6	−12
14	− 1	− 5	− 10	−15	− 9	−13	− 20	−24	− 10	−14
15	− 8	− 6	− 11	−16	− 12	−14	− 23	−24	− 12	−15
16	− 14	− 7	− 12	−16	− 14	−14	− 26	−23	− 16	−15
17	− 15	− 7	− 14	−14	− 13	−12	− 26	−20	− 17	−13
18	− 12	− 6	− 14	−12	− 12	−10	− 26	−14	− 16	−10
19	− 5	− 5	− 14	− 8	− 8	− 7	− 17	− 8	− 11	− 7
20	0	− 4	− 11	− 4	− 4	− 4	+ 4	0	− 3	− 3
21	+ 2	− 2	− 5	+ 1	0	0	+ 16	+ 8	+ 3	+ 2
22	+ 3	+ 1	+ 2	+ 6	+ 4	+ 4	+ 22	+16	+ 8	+ 7
23	+ 3	+ 3	+ 10	+11	+ 8	+ 8	+ 25	+23	+ 12	+11
0	+ 4	+ 5	+ 18	+15	+ 12	+12	+ 28	+29	+ 16	+15

A second approximation was made to the clock corrections, employing the diurnal term. The resulting corrections were

$$\Delta\alpha_a = -0^{s}.0093 \sin \alpha + 0^{s}.0076 \cos \alpha$$

Observers.	N—D.
R. H. Tucker.........	+.008
A. J. Roy.............	−.012
W. B. Varnum........	−.019

The close agreement of these values with those of the first approximation rendered a second approximation to the diurnal term unnecessary; nor was it deemed necessary to further refine the terms

$\Delta\alpha_a$ and N − D. They have been applied in deriving the definitive clock corrections. These clock corrections have been applied to the clock stars and the observations are now being collected preparatory to forming the definitive places.

The work of reducing the right ascensions of the 87,000 San Luis observations has continued and is in a forward state.

The collimations and levels for the Albany observations of 1907–08 have been determined and some progress has been made in reducing these observations.

In the zenith-distance reductions considerable progress has been made. For the current work the error of runs has been determined at short intervals and these, together with the division errors, have been largely applied, the results being drawn off in duplicate for the further application of the various corrections to follow.

In training new men as microscope readers, it has been found that enough errors are made by experienced readers to call for an examination of the readings of individual microscopes. As handy tables can be formed for this purpose, the actual time consumed counts for little when compared with the added accuracy. The current circle-readings are undergoing the same treatment.

Readings on circle A have been made for the determination of its eccentricity, to be utilized in the formation of a table for the further examination of the readings on single microscopes.

A preliminary determination has been made of the latitude of San Luis, from the observations of stars taken above and below pole. In the reductions of the observations the Pulkova refractions were used. The preliminary results indicate a considerable correction, part of which is due to uncorrected telescope flexure.

The San Luis reflection observations have also been reduced and a preliminary examination of the results made. While these results will not be discussed at present, there is an indicated cosine flexure of about $+ 0''.3$.

The further reduction of the San Luis zenith distances is awaiting the termination of the correction of circle readings.

ZONE CATALOGUE.

The zone catalogue for which the majority of observations were taken from 1896 to 1900 will shortly be ready for the printer. This catalogue contains 11,000 stars, principally included in the zone −23° to −37°. During the past year 800 observations taken in 1891–2 have been reduced to the system of the 1896–1900 work, and all of the stars catalogued. The checking of the final places was performed by Mr. Roy. Comparisons were made with other catalogues to catch large errors, and while few errors were found, many appreciable proper-motions were discovered. The checking of the manu-

script for the printer is well advanced. It has been decided, however, to delay publication, awaiting a systematic search of the catalogue for large proper-motions. This work, which has already been started, will be pushed to an early termination in order that the catalogue may be speedily published.

PHOTOMETRIC OBSERVATIONS AT SAN LUIS.

The photometric expedition to San Luis terminated in February 1913, and the instrumental equipment was returned to Albany.

The object of the expedition was the determination of the magnitudes of those stars on our observing list, in the southern hemisphere, which had not been observed by Harvard, the Harvard system being used as a base to which our observations should be differentially tied.

The photometer employed in this work is designed to bring the magnitudes of the star and an artificial star to equality by reducing the light of the artificial star by means of a wedge. 20,758 observations were taken, including the observation of fundamentals; 12,769 by M. L. Zimmer and 7,989 by Heroy Jenkins. The number of Harvard comparison stars observed was 1,328, for the determination of 6,725 stars. It was intended that each star to be determined should receive two observations, and with few exceptions this plan was followed. In some cases three observations were secured.

The preliminary reductions of these observations have been carried out. They indicate a probable error of $\pm 0^{M}\!.08$ for a single observation, or $\pm 0^{M}\!.06$ for two.

The mean value for absorption is $0^{M}\!.25$ (sec. $z-1$), the value obtained for the northern Harvard measures, though somewhat larger than the mean of the values for the Arequipa station. While the absorption from individual nights at times deviated considerably from the mean value, in general there was little difference, and as the zenith distance of the south pole was only 57°, an error of $0^{M}\!.1$ in the absorption would introduce an extreme error of $0^{M}\!.08$ in the derived magnitudes. The mean value for the absorption has therefore been used in the reductions.

Aside from the observations mentioned, about 2,500 observations were taken for the determination of the scale value.

BUILDINGS AND APPARATUS.

The standard Riefler clock was not sealed when mounted after its return from San Luis. As this clock evidenced considerable but inconsistent changes with variation in barometric pressure and temperature, it was deemed advisable to seal the glass cases inclosing the clock. Previous attempts at sealing had proved failures. Therefore care was taken to repack the valve through which the winding rod passes. All possible air-passages were tested by immersing the

cylinder in water after a partial vacuum had been established, thus drawing water through all points of leakage. These points were marked and in sealing especial care was given them, though every joint was carefully gone over with several coats of cement. Three cements received trial, but in each case a gradual leakage took place. The attempt at sealing was consequently given up and it was deemed necessary to secure another clock, which has the additional advantage of assuring the continuity of observation in case one clock breaks down.

Steps have been taken toward obtaining a temperature control for the clock-room, in order to secure as nearly as possible a constant temperature.

Upon the termination of the photometric expedition to San Luis, the buildings were turned over to the Argentine government.

STAFF.

Mr. A. J. Roy has continued as observer in charge of the meridian circle and has also had charge of part of the work of reduction of observations. He is also responsible for the preparation of the observations of the zone catalogue of 1896–1900 for the printer.

Mr. W. B. Varnum, besides his duties as observer, has had charge of the reductions of the San Luis right ascensions.

Mr. H. Raymond has been employed as observer and microscope reader. He has aided the acting director in his investigations and has been otherwise employed upon important parts of the work.

Mr. Heroy Jenkins returned to Albany from San Luis in March 1913. At San Luis he was engaged in the observation and reduction of the photometric work. Upon his return to Albany he resumed his duties as microscope reader.

Mr. S. B. Grant has continued as microscope reader, being variously employed upon the computations.

Mr. Meade L. Zimmer, who was in charge of the photometric expedition to San Luis, resigned from the department at the expiration of the work in March, to accept the position of chief assistant at the Cordoba National Observatory.

Dr. Sebastian Albrecht, who has been junior professor of astronomy in Detroit Observatory, has accepted the position of astronomer, commencing his duties October 1, 1913.

In addition, there are 9 computers and a varying number of piece-work computers.

PLATE 5

PASADENA OFFICE BUILDING, SOLAR OBSERVATORY.

MOUNT WILSON SOLAR OBSERVATORY.*

George E. Hale, Director.

The persistence of the period of minimum solar activity, marked by the almost complete absence of sun-spots and other evidences of disturbance, has been an important factor in the work of the year. While it has prevented a continuance of our observations of sun-spot phenomena, compensation has been found in the study of the sun's general magnetism, where the minute manifestations of the Zeeman effect might be wholly masked by the prevalence of the hundredfold greater displacements caused by local magnetic fields. For this investigation the completion of the 150-foot tower telescope was most opportune. In exploring the magnetic phenomena of the sun's polar regions the large solar image given by the new telescope is indispensable, while the great dispersion of the 75-foot spectrograph is no less essential for the detection of the barely measurable displacements of the solar lines on which the investigation is based. The direct observational evidence of the sun's magnetism now appears to be beyond question, leaving us free to advance from the period of proof into that of definitive research on the nature of this important phenomenon.

In certain other fields of solar research, as Mr. St. John's admirable results attest, there has also been no interruption of progress. Great activity has also marked the prosecution of the stellar and laboratory work, especially in Mr. Adams's department, where the measurement of stellar velocities has continued at an unprecedented rate. In the selection of objects for study, and in the discussion of the data obtained, Professor Kapteyn has exercised his usual sound discrimination and breadth of view. The evidence he has amassed in support of the view that light is absorbed in space is so impressive that we intend to devote much attention to this subject in the future. It not only offers an explanation of otherwise obscure phenomena, but promises to give what appears to be the only possible method of measuring the most profound depths of the universe. The important results obtained by Professor Störmer, of Christiania, in his theoretical investigations of solar vortices; by Professor Hertzsprung, of Potsdam, in his Mount Wilson observations bearing on the absorption of light in space; and by Professor Koch, of Munich, in applying his registering micro-photometer to the study of our solar, stellar, and laboratory spectra, are interesting features of the present report.

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*Situated on Mount Wilson, California. Address Pasadena, California. Grant No. 866, $165,631 for construction, investigations, and maintenance during 1913. (For previous reports see Year Books Nos. 3–11.)

The principal results of the year may be summarized as follows:

(1) Observations of the Zeeman effect at various solar latitudes indicate that the sun is a magnet, with magnetic poles at or near the poles of rotation.

(2) The polarity of the sun corresponds with that of the earth—a conclusion which may prove to have an important bearing on theories of terrestrial magnetism.

(3) If, in harmony with one of these theories, the magnetism of the sun is caused by the axial rotation of a body acting as though it carried a residual volume charge, the sign of the charge comes out negative.

(4) Many of the solar lines fail to show the Zeeman effect due to the sun's general field. A tentative hypothesis ascribes this fact to a rapid decrease in the strength of the field at increasing levels in the solar atmosphere.

(5) A first approximate value for the vertical intensity of the sun's general field at the poles is 50 gausses, which is about one-hundredth of the intensity of the most powerful sun-spot fields and about 80 times that of the earth's field.

(6) For a normal Zeeman triplet the theoretical curve of displacements produced in the spectrum by the sun's general magnetic field is a sine curve, with zero values near the equator and the poles and maxima near 45° north and south latitudes.

(7) The effect on these displacements of the elliptical polarization produced by the mirrors of the tower telescope is negligible under the normal conditions of observation.

(8) An extended investigation of radial motion in sun-spots gives results in entire accord with Evershed's hypothesis that the line displacements are due to a movement of the solar vapors tangential to the solar surface and radial to the axis of the spot vortex.

(9) The proportionality between displacements and wave-lengths shows that the phenomenon represents an actual flow of the gases of the reversing layer out of spots and of the chromospheric gases into spots.

(10) The outward velocities increase with distance below a neutral level, while the inward velocities increase with distance above this level, which is the level of velocity inversion.

(11) A consideration of the quality and the quantity of the materials and of the amount of energy involved in the flow inward at high levels and the flow outward at low levels indicates that they do not of themselves form a vortex system.

(12) The type of vortex indicated is that of the terrestrial tornado or hurricane. The actual vortex is deep-seated, the outflow into the reversing layer being a portion of its upper part, while the inflow from the chromosphere is a secondary effect.

(13) The secondary phenomenon sometimes shows vortex motion of the high-level calcium vapor, visible evidences of vortex movements, and stream-line structure of the *Hα* flocculi, depending upon the strength of the magnetic field and the rotational energy of the underlying vortex.

(14) The structure of the hydrogen flocculi does not represent true stream-lines, but lines of force due to the low-level vortex which produces the magnetic field.

(15) The dominant charge of the electrons in this low-level vortex is negative.

(16) The observed decrease in the strength of the field along the axis of the spot can be accounted for by assuming the thickness of the electric vortex to be about equal to its diameter.

(17) The forms of prominences surrounding a sun-spot at the sun's limb closely resemble lines of force projected in a meridian plane.

(18) The absence of stream-line structure in the H_2 flocculi follows from the quiescent state of the calcium vapor producing these flocculi.

(19) The flux of gases into and below the lower portion of the reversing layer would cause a piling up of material, raised to a high temperature by the rapid transformation of the chemical energy into heat, and resulting in the observed increased emission of the calcium vapor.

(20) When the displacements of lines in the red and violet of equal solar intensities are compared, the lines in the violet show the smaller displacements and therefore originate at higher levels, a consequence of the scattering of light.

(21) The displacements of the Fraunhofer lines in the penumbræ of sun-spots give means of sounding the solar atmosphere and of assigning relative levels to the sources of the lines. Aside from the inherent probability of the interpretation, it is confirmed by eclipse results, is in harmony with a wide range of solar observations, and opens the way to further solar research.

(22) With the aid of the relation between displacement and intensity found for the iron lines, the relative levels of 26 other elements of the reversing layer and chromosphere have been determined.

(23) The H_3 and K_3 lines of calcium, followed by *Hα* of hydrogen, represent the highest level. In general, the heavy elements occur only in the lower portions of the solar atmosphere.

(24) The enhanced lines appear to originate at higher levels than the unenhanced lines.

(25) The iron lines of different pressure groups are associated with different levels.

(26) The quantity of absorbing vapors in the solar atmosphere seems sufficient to produce in general complete absorption.

(27) Large positive radial displacements are associated with low heights above the photosphere and large negative displacements with great heights, when a comparison is made between radial displacements and elevation deduced from eclipse results.

(28) The mean radial displacement of lines of the reversing layer occurring frequently in flash spectra is +0.009 Å; of those observed less frequently it is +0.023 Å.

(29) A comparison of the radial displacements with the weakening and strengthening of spot lines shows that strengthening increases with depth and that weakening is associated with high elevations.

(30) A discussion of the displacements between the center and limb of the sun from the point of view of levels indicates that pressure plays the predominating role, but that the effect is modified by the scattering of light in the lowest levels and by the downward movement of the high-level vapors.

(31) When the Mount Wilson rotation results are compared with the corresponding radial displacements, a remarkable agreement is found. Low values for solar rotation are associated with large positive radial displacements, and high values for rotation with large negative radial displacements. The data in both cases place the level of the lanthanum lines below and the level of the hydrogen lines above the mean level of the reversing layer.

(32) Different lines give widely different field-strengths for the magnetic fields of sun-spots, but when the lines are assigned to the relative levels indicated by their radial displacements the field-strength decreases consistently with elevation.

(33) Judged by the criteria which indicate the presence of anomalous dispersion, the radial displacements in the penumbræ of sun-spots are not due to this cause.

(34) A critical investigation of 53 international secondary standards shows no errors in relative wave-length exceeding 0.002 Å.

(35) The secondary standards belong to pressure groups *a*, *b*, *c* 4, *c* 5, and sub-*d*, and the quality of the lines of the several groups is in the order given.

(36) It would be a gain if all the lines of group sub-*d* could be replaced by lines of better quality. This is feasible for the region λ 5192–λ 5324, where excellent lines of group *a* are well distributed.

(37) From a comparison of the measured intervals between close pairs of lines, it appears that the wave-lengths of the components can not be determined with sufficient accuracy to fit them for standards.

(38) In the case of reversed lines, the measurements made upon the sharp reversals are the most reliable.

(39) The change in relative wave-length between Pasadena and Mount Wilson, caused by difference in atmospheric pressure, is less easy to substantiate in the blue-green than in the red region, but it appears distinctly in the means.

(40) The large discrepancies between observers in the case of lines of groups *d* and *e* appear to be attributable to the marked unsymmetrical broadening of these lines near the negative pole of the arc.

(41) To eliminate the effect of this polar dissymmetry it is recommended that the slit of the spectrograph be placed at right angles to the axis of the arc at the middle point of the enlarged image.

(42) The consistency of the various series of wave-length investigations may be attributed to two constant factors, the complete analyzing action of the plane grating and the uniform arc conditions.

(43) The color index of the *Algol* variable *RR Draconis* increases by 0.57 mag. as the star approaches minimum.

(44) Since the eclipse is total, and the secondary star very faint, this change in color measures the difference in spectral type of the two components, indicating probable values of A2 and F5.

(45) Observations of the stars of the North Polar Sequence give magnitudes between 10.5 and 15.5 which are in excellent agreement with the Harvard Observatory results.

(46) For the brighter stars there is a considerable divergence from the Harvard scale.

(47) During the year 199 plates have been obtained of a total of 460 required to determine the relative photographic magnitudes of standard stars in the Kapteyn Selected Areas.

(48) For the purposes of classification and the measurement of radial velocity, 1,061 stellar spectrograms have been taken during the year.

(49) Radial velocity determinations are now completed for a total of 372 constant velocity stars of various types.

(50) The total number of spectroscopic binary stars hitherto discovered at Mount Wilson is 99.

(51) The absolute motions in space of 61 stars with measured parallaxes have been calculated from radial velocity determinations. Twenty of these have absolute velocities ranging from 100 km. to more than 300 km. per second.

(52) A group of 9 stars, having a common radial velocity of -43 km. per second, has been found in the *h* and χ *Persei* clusters.

(53) Thirteen months after the discovery of *Nova Geminorum* No. 2, its spectrum still showed marked absorption lines.

(54) The bright bands remain without change in width or displacement, but the hydrogen band at λ 4686 has fluctuated greatly in intensity.

(55) The companion of *Rigel*, though about seven magnitudes fainter than the principal star, has an almost identical spectrum.

(56) The spectra of 19 stars in the *Hercules* cluster *M* 13 range in type from A0 to G0.

(57) In harmony with previous results, the brightness of the night sky does not appear to be due exclusively to direct starlight.

(58) Nearly 300 helium stars between galactic latitudes ±30° and longitudes 217° to 360° apparently belong to a single group.

(59) Over 200 stars in the cluster *N. G. C.* 1647 show a systematic change of color index with magnitude, indicating that the fainter stars are redder than the brighter ones.

(60) This fact, together with a large mass of evidence gathered from various independent sources, strongly indicates that light is absorbed in its passage through space, and promises to afford a method of determining the order of distance of the most remote stars.

(61) An investigation of the luminosity curve for stars of various spectral types is providing data for the study of the arrangement of stars in space.

(62) In the electric-furnace spectra of iron and titanium 512 iron lines and 625 titanium lines have been classified on the basis of their change of intensity with temperature.

(63) The blue end of the furnace spectra of both iron and titanium first appears at a lower temperature than the red end, and the distribution of line intensities does not resemble the intensity gradation of the continuous spectrum of an incandescent solid.

(64) Lines of a certain class are relatively much weaker in the arc than in the furnace spectrum.

(65) The banded spectrum attributed to titanium oxide does not appear in the furnace spectrum at reduced pressure, thus confirming the view that it belongs to the oxide.

(66) Enhanced lines appear with great strength in the low-voltage "tube-arc" spectrum, which also contains hydrogen lines and the line spectrum of carbon.

(67) The production of the enhanced lines seems to be related to the high degree of ionization in the "tube-arc."

(68) Ionization currents in the electric furnace fall rapidly with increase of pressure up to 4 atmospheres, after which they decrease slowly, and are still appreciable at 20 atmospheres.

(69) Many lines which are sharp and narrow in the center of the arc show great widening and lack of symmetry at the negative pole, together with marked increase of intensity.

(70) A general investigation of the Zeeman effect for iron, chromium, vanadium, and nickel has yielded valuable data for the interpretation of solar phenomena.

(71) The chromium line $\lambda 4254$ is split into 21 components by a very intense magnetic field.

(72) Koch's recording micro-photometer has proved to be of great value in the study of the intensities and displacements of solar, stellar, and laboratory spectra.

STAFF.

A return of his previous illness required the Director to be absent from the middle of March until early in August. During the rest of the year he has devoted as much time as could be spared from other duties to the study of the general magnetic field of the sun.

Dr. Walter S. Adams, to whom the Director is indebted for much valuable aid, was appointed Assistant Director in January. During the Director's absence he was in charge of the Observatory, and throughout the year he has continued at the head of the department of stellar spectroscopy. Professor F. H. Seares has remained in charge of the Computing Division and the editorial work, and has continued his researches in stellar photometry. He has also completed a theoretical study of the general magnetic field of the sun and prepared an extended report on the present state of the photographic process. Dr. Arthur S. King has continued his investigations as superintendent of the physical laboratory, devoting most of his time to problems connected with the electric furnace. Dr. Charles E. St. John has extended his spectroscopic work on the sun with the 150-foot tower telescope, and has also pushed forward his study of the secondary standards of wave-length in the spectrum of iron. Mr. Ferdinand Ellerman has devoted most of his time to observational work with the 150-foot tower telescope in connection with the general magnetic field of the sun. Mr. Ellerman, Dr. Adriaan van Maanen, Mr. Charles S. Backus, and Mr. Walter T. Whitney have carried on the daily observations of the sun with the 5-foot spectroheliograph. Mr. H. D. Babcock has pursued his laboratory investigations with special reference to the Zeeman effect and the wave-lengths of the arc lines. Mr. F. G. Pease has continued his systematic photographic study of nebulæ and star clusters with the 60-inch reflector and has also made some photographs of these objects with a new low-dispersion spectrograph, in addition to his work of instrument designing. Dr. Arnold Kohlschütter returned to the Observatory the latter part of April, after an absence of six months in Germany, and has devoted most of his time to stellar spectroscopic observations and the classification of stellar spectra. Dr. van Maanen, who joined the staff September 1, 1912, has measured all of the photographs of spectra taken for the study of the general magnetic field of the sun. He has also assisted in the stellar spectroscopic work during the absence of Doctor Kohlschütter. Mr. Backus resigned from the Observatory staff December 1, 1912. Mr. Whitney, who joined the staff February 15, 1913, as assistant in both stellar and solar work, resigned his position August 15, to pursue further studies in the University of Chicago.

Professor J. C. Kapteyn, Research Associate, has spent several months on Mount Wilson, continuing his studies of star-streams and

related problems. Professor Carl Störmer, of the University of Christiania, Research Associate during 1912, has completed his theoretical investigation of unipolar hydrogen flocculi. Professor Peter Paul Koch, of the University of Munich, who arrived in Pasadena early in August, is investigating the applications of his registering microphotometer to the measurement of solar, stellar, and laboratory spectra. Dr. J. A. Anderson, of the Johns Hopkins University, has been engaged during the year on the design and construction of a machine for ruling diffraction gratings. Mr. P. J. van Rhyn has remained with the Observatory as volunteer assistant and has devoted his time to the study of the color indices of selected stars and to other problems relating to the general question of the absorption of light in space.

Mr. L. B. Aldrich, of the Smithsonian Institution, has continued the regular solar-constant work of the Smithsonian Astrophysical Observatory during the absence of Director C. G. Abbot, who returned to Mount Wilson September 1.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

Instruments.

Several important additions and accessories have been provided for the 150-foot tower telescope and the 75-foot spectrograph. These include the permanent mountings for the 30-foot and 60-foot objectives of the tower; a permanent water-circulation system for controlling the temperature of the cœlostat and second mirrors, to replace the temporary arrangement used experimentally last year; and certain minor accessories. The temporary wooden house at the summit of the tower has also been replaced by one of metal, which is larger and more commodious, and provides perfect protection for the instruments in the most severe winter storms.

Our favorable opinion of the 150-foot tower telescope, based upon preliminary observations, has been confirmed by the experience of the past year. The vertical tube, which is provided with a double sheathing of metal and an outer sheathing of canvas, with intervening air-spaces, is so completely protected against heating that no difficulty whatsoever is experienced from convection currents. This is clearly shown by the behavior of dust particles floating in the tube above the spectrograph and illuminated by the beam of sunlight. These are as quiet and undisturbed as in the air of a tightly closed room.

The trouble at first experienced from distortion of the mirrors by heating of the edges has been so completely surmounted by the circulation of water through the cells surrounding the glass that all astigmatism has disappeared, and the change of focus has been reduced to so small an amount that it is no longer a source of any

difficulty. This is true even when the objective of 150 feet focal length is employed. It is a satisfaction to record the final solution of a difficulty which threatened to be serious.

The great number of plates required for the study of the general magnetic field of the sun has made it necessary to devote most of the time of the 150-foot tower telescope to this subject, and for this reason comparatively little has been done with the spectroheliograph. Monochromatic images of the sun have nevertheless been obtained with both high and low dispersion, and the results are so satisfactory that much use will be made of this spectroheliograph as soon as the solar activity increases.

The heliomicrometer has been moved from its former position at the rear of the shop building to its permanent place in the basement of the new office building. Installed on a massive pier, under the most favorable conditions for use, this instrument is available for a variety of work.

The remarkably successful application of Professor Koch's registering microphotometer to the determination of the positions and intensity curves of solar and stellar lines will have an important bearing on future research. The positions of symmetrical lines on photographs of spectra can be measured with this instrument to about 1 micron, and since increase in their width involves no greater difficulty in measurement, the precision becomes directly proportional to the linear dispersion and hence to the focal length of the spectrograph. Thus the advantages in solar research of such an instrument as the 75-foot spectrograph, which have already appeared in the detection of the sun's magnetic field, will be multiplied several fold by this powerful auxiliary.

Direct Photography of the Sun.

During the year ending August 31, 1913, 222 direct photographs of the sun were obtained with the Snow telescope. On account of the low state of the solar activity, the very few spots recorded have been small and unimportant.

Work with the 5-foot Spectroheliograph.

During the year 813 photographs of the sun have been made on 297 days with the 5-foot spectroheliograph, using $H\alpha$ and K_2 for the disk and $H\alpha$ for the prominences at the limb. Since February 17, 1913, photographs of the prominences have been made with both $H\alpha$ and K_2, in order to provide material for a comparative study of the distribution of hydrogen and calcium.

The measurement of the areas of the calcium flocculi and prominences has been continued by Miss Smith, whose reductions are complete to August 1, 1913. Miss Smith has also made 502 prints of spectroheliograms, which have been bound for reference in continuation of the previous series.

General Magnetic Field of the Sun.

In the last annual report it was stated that observations were in progress with the view of determining whether the sun has a general magnetic field sufficiently intense to produce a measurable Zeeman effect. This investigation has been continued throughout the year, with results which now seem to leave no doubt as to the existence and order of intensity of the sun's magnetic field. The minimum of solar activity has proved peculiarly advantageous for this work, as it has eliminated the disturbing influences which would result from the magnetic fields in sun-spots, which are occasionally as much as 100 times as intense as the general field.

During the year 197 photographs of spectra have been taken for the purposes of this investigation, most of them by Mr. Ellerman. The region to which special attention has been directed is in the third-order spectrum of the 75-foot spectrograph, including the lines λ 5812.129 (*Fe*, 0), λ 5828.097 (—, 0), and λ 5929.898 (*Fe*, 2). Since the conclusion of the preliminary investigation a number of photographs have been taken of other regions, for the purpose of finding additional lines which show the Zeeman effect due to the general field.

The various precautions taken to eliminate possible instrumental errors are fully described in a paper entitled "Preliminary results of an attempt to detect the general magnetic field of the Sun," published in June as No. 71 of our series of Contributions. During the past year all of the photographs have been measured by Mr. van Maanen with a parallel-plate micrometer, which has proved to be more satisfactory than a filar micrometer for the measurement of the comparatively broad lines photographed under such high dispersion. The following table gives the mean displacements for various latitudes obtained by Mr. van Maanen for λ 5930 in the first and third series of observations, and for λλ 5812 and 5828 in the fourth series of observations. The unit is 0.001 mm. = 0.0002 Å.

Lat.	Δ	No. of observations.	Lat.	Δ	No. of observations.
N. 68.8°	+2.2	15	S. 5.1°	−0.8	15
59.4	+3.6	15	14.3	−2.4	15
55.4	+5.1	16	24.2	−3.6	15
50.3	+4.4	15	34.1	−4.3	15
46.1	+4.1	15	37.7	−4.6	15
44.5	+6.0	15	41.0	−4.7	15
41.9	+5.7	15	45.1	−5.8	16
39.3	+5.1	15	47.1	−4.7	15
36.7	+3.0	15	49.9	−4.1	15
33.9	+2.9	15	51.7	−4.1	15
25.7	+2.7	15	52.8	−4.7	15
18.0	+3.1	16	57.3	−4.1	15
12.7	+0.8	15	60.5	−3.5	15
7.3	+1.6	15	64.5	−2.5	15
N. 0.5	0.0	15	70.0	−1.1	15
			S. 78.1	+0.1	15

The table shows the reversal of the sign of the displacement in the opposite hemispheres of the sun and the decrease in the values from 45° north and south latitude toward the equator and the poles. When these observations are plotted, they are found to agree very closely with the theoretical curve described below.

Since the conclusion of the preliminary investigation with the three lines mentioned, Mr. van Maanen has measured other selected lines with the results indicated in the following table:

Wave-length.	Element.	Intensity.	Displacements.			Total number of measures.	Discarded in forming curve.	Maximum of curve.	Behavior in sun-spots.
			Right sign.	Wrong sign.	Zero.				
5804.681	*Fe*	0	18	20	0	38	....	....	
*5831.821	*Ni*	1	94	28	3	125	10= 8 p. ct.	2.9	
5838.592	*Fe*	1	19	19	0	38	....	....	Prob. doublet.
5848.242	*Fe*	3	15	16	1	32	....	....	
*5856.312	*Fe*	2	64	9	2	75	5= 7 p. ct.	4.1	
5892.920	*Fe*	00	7	9	0	16	....	....	
5905.895	*Fe*	4	15	18	6	39	....	....	
5916.475	*Fe*	3	25	31	3	59	....	....	Doublet.
*5928.013	*Fe*	2	74	18	2	94	12=13 p. ct.	2.8	
5991.600	....	2	22	25	4	51	....	....	
5998.002	*Fe*	2	23	26	3	52	....	....	
6005.770	*Fe*	1	31	38	4	73	....	....	Doublet.
*6007.540	*Ni*	1	54	17	1	72	14=19 p. ct.	3.4	Doublet
6012.450	*Ni*	1	22	16	1	39	....	....	Triplet.
*6039.953	*V*	0	78	6	1	85	6= 7 p. ct.	5.8	Prob. doublet.
6042.315	*Fe*	3	31	26	3	60	....	....	
*6079.227	*Fe*	2	94	12	2	108	9= 8 p. ct.	4.2	Prob. doublet.
*6119.740	*V*	1	74	9	0	83	8=10 p. ct.	4.4	
6455.820	*Ca*	2	32	38	2	72	....	....	Prob. doublet.
6496 688	*Fe*	2	41	34	3	78	....	....	Doublet.
6597.807	*Cr*	1	32	44	0	76	....	....	Prob. doublet.

Seven lines in this table, which are indicated by asterisks, show a marked preponderance of displacements of the right sign. Accordingly, an approximate reduction of these observations was made, with the results indicated in the ninth column of the table, which gives the maximum of the displacement curve expressed in thousandths of a millimeter. A large number of other lines are now being measured, in order to determine what elements show the effect and to give a preliminary determination of its magnitude at different levels in the solar atmosphere. As the work of measurement is slow and tedious, some time may elapse before the definitive investigation can be begun.

It appears to be quite safe to conclude, from the extensive series of measurements already completed, that the sun is a magnet, with poles falling at or near the poles of rotation. An approximate determination of the strength of the magnetic field gives a value of about 50 gausses for the vertical intensity at the sun's poles. Hence the sun's field, at the level in question, is some 80 times as intense as that of the earth. As for the polarity of the sun, it is interesting to

find that it corresponds with that of the earth, *i. e.*, the north magnetic pole lies near the north pole of rotation.* While this analogy may prove to be important in the further consideration of various theories of the earth's magnetism, there is one respect in which the sun's field may differ very materially from that of the earth. As various solar lines exhibiting large Zeeman effects in the laboratory have failed to give any indication of the sun's field, and as the great majority of the lines which show displacements are produced at low levels in the sun's atmosphere, it seems probable that the intensity of the field must fall off very rapidly in passing upward from the surface of the photosphere. This point will be the subject of a careful investigation as soon as the necessary material becomes available.

A determination of the exact position of the magnetic poles with respect to the poles of rotation will be made as soon as suitable observational data can be obtained.

Professor Koch's registering micro-photometer is being tested in the measurement of the displacements on general magnetic field spectra. The results, as far as they go, confirm those obtained with the parallel plate micrometer, but definitive work must await the construction of an instrument giving more accurate relative motion of the negative and the plate on which the curve is photographed.

Soon after it appeared that the displacements observed in the above investigation were reasonably attributable to the Zeeman effect, Dr. Anderson was requested to calculate the displacements of a normal Zeeman triplet at various latitudes, assuming the source to be in the field of a uniformly magnetized sphere. The resulting sine curve was later the subject of a valuable theoretical study by Mr. Seares, which has supplied the formulæ required for the reduction of the measures. For a normal triplet the theoretical displacement curve is a function of the heliographic latitude, the position of the observer, and the solar magnetic elements. As already stated, it is a sine curve having zero values near the equator and the poles and absolute maxima near 45° north and south latitudes. Mr. Seares's theoretical investigation included the effect of the elliptical polarization produced by the mirrors of the tower telescope, which are found, under the actual conditions of observation, to flatten the curve of displacement by a negligible amount.

Spectrum of the Chromosphere.

Miss Burwell has measured 12 photographs of the spectrum of the chromosphere during the year, but unfavorable weather and the constant need of the 150-foot tower telescope for observations of the

*The nomenclature ordinarily used by terrestrial magneticians is followed here. As a matter of fact, the magnetic poles in the northern hemispheres of the sun and earth are "south" poles.

general field of the sun have hindered progress in this investigation. The delay is not serious, however, as much better photographs can probably be obtained when the sun is more active than at present.

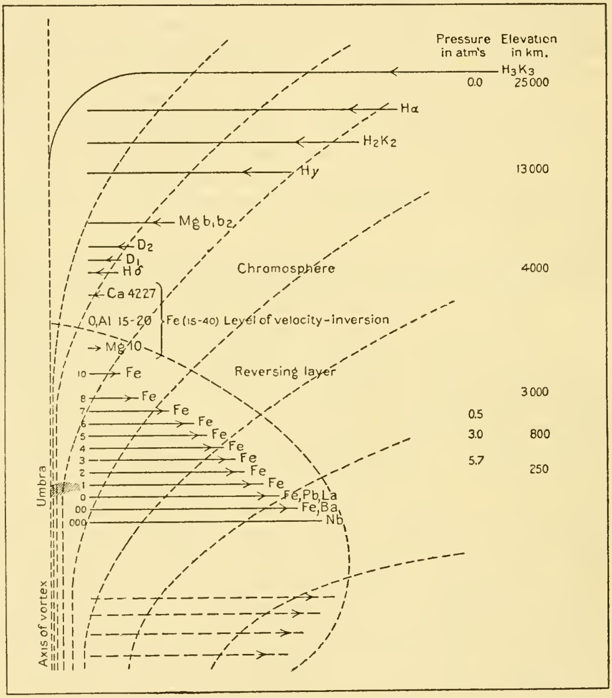
Radial Motion in Sun-spots.

Mr. St. John's investigations on the radial motion of the vapors in the solar atmosphere above sun-spots have been greatly extended during the year. In a paper published as No. 69 of the Observatory Contributions he has given his results on the distribution of velocities in the solar vortex, together with a discussion of various phenomena connected with the theory of sun-spots. The program of observations has included the measurement of radial velocities for 506 lines representing 27 elements, lying at levels extending from the lowest that can be observed to the highest regions of the chromosphere. The method of observation employed has yielded results of high precision, which may be depended upon to represent the facts very closely indeed.

An examination of the absolute displacements shows that the large displacements are associated with the longer wave-lengths, as must be the case if they are really due to motion of the vapors in the line of sight. Another important fact is the systematic variation of the displacements with the intensities of the Fraunhofer lines. The mean displacements of 193 iron lines of intensities 1 to 8, when reduced to a common wave-length, show a gradual decrease in velocity from 1.68 km. per second for lines of intensity 1 to 0.54 km. per second for lines of intensity 8. If the series of iron lines be extended so as to include those from intensity 00 to the very strong lines of intensity 15 to 40, thus covering the entire range, an iron scale is provided which forms a practical and convenient means of determining the relative levels in the solar atmosphere at which the lines of other elements are produced. For these lines the flow of the gases is outward and tangential to the solar surface, and if, as the evidence indicates, the weaker lines originate at the lower level, the velocity outward increases with the depth. The results also show that the mean level of the lines in the red is about two units of intensity lower than in the violet; that is, lines of intensity 4 in the red are at about the level of lines of intensity 2 in the violet, and similarly for lines of other intensities. Such a difference is the natural consequence of the scattering of light by small particles, which varies inversely as the fourth power of the wave-length. From this it would result that we see into the sun to a greater depth in the red than in the violet.

The distribution of velocities in sun-spots is shown by the accompanying figure, which represents a vertical section through the axis of the vortex. In the lower portion, corresponding to the effective levels of the reversing layer, the velocities are mainly those given by the iron lines; in the upper portion, which refers to the chromosphere,

the identification of the lines is given in connection with the plotted velocities. The ordinates are entirely arbitrary. They are only meant to indicate the increasing velocities of inflow with increasing elevation above the region of velocity inversion and the increasing velocities of outflow as the depth increases below this level. At the right are given some elevations taken from Jewell's table, which is based upon eclipse observations of the levels of bright lines in the



Vertical Section of Reversing Layer and Chromosphere, showing Distribution of Radial Velocities of Sun-spots.

The lengths of solid lines are proportional to radial displacements of the corresponding Fraunhofer lines. Arrows indicate direction of flow. The rounded head of the cyclonic disturbance is suggested by the broken-line curve enveloping the outward velocities. Broken lines with arrows refer to possible velocities below the accessible levels. Lines of force of the magnetic field are indicated in the usual way.

flash spectrum. In the diagram are also given results obtained in the course of an extended investigation of pressures in the solar atmosphere, upon which considerable reliance can be placed when it is a question of the variation of pressure with depth.

It seems safe to conclude, from the evidence presented, that the outward velocities in the reversing layer at the outer boundaries of

the penumbræ of sun-spots may be referred, with great probability, to a low-lying vortex. The inflow of the chromospheric gases seems to follow (in part, at least) from the general downward movement of these gases. Professor Störmer's investigations indicate that the production of stream-line structure in the *Hα* flocculi is probably due to the magnetic field, which may act mainly as a directing force upon the inward-moving ions. At the level of the H_2 calcium flocculi the relatively quiescent state of the gases and the great inertia of the calcium ions are conditions very unfavorable to the formation of stream-lines. Hence, as observation indicates, these should appear most clearly at the higher level of the *Hα* flocculi. On the basis of Professor Störmer's theory, there would probably be some relationship between the definiteness of the lines of force structure and the strength of the field in the spot. An examination of the evidence seems to indicate that this is the case.

In a second paper on radial motion in sun-spots, Dr. Charles E. St. John gives a very comprehensive and illuminating discussion of the distribution of the elements in the solar atmosphere. When the displacements of the lines of different elements are compared, it appears that the displacements of lines of like intensity differ. By the aid of the iron scale referred to above, it is possible to determine the relative levels in terms of this scale at which the lines of other elements are produced. In this way a chart has been plotted which represents the distribution of the various elements in the solar atmosphere and offers a convenient means of finding the approximate level represented by a line of given intensity belonging to any of these elements.

Many important conclusions reached in the paper are summarized in the introduction of this report. Its chief feature is a discussion of the bearing of Mr. St. John's results on eclipse observations, modification of spot lines as a function of level, displacements at the sun's limb, solar rotation and level, magnetic field and level, anomalous dispersion, and solar and terrestrial analogies. In all cases a remarkably close agreement is found between the levels represented by the radial displacement measures and those indicated by other classes of observations. It is evident that great possibilities of research lie open in this field, which promises us a more intimate knowledge of the solar atmosphere than we now have of the atmosphere of the earth.

Tertiary Standards with the Plane Grating.

In a second paper on the testing and selection of standard lines of the international system, Mr. St. John and Miss Ware have examined the secondary standards from λ4282 to λ5506 as to their consistency among themselves, and have determined the wave-lengths in international units of a series of 198 lines in the arc spectrum of iron from λ4118 to λ5506. The region from λ5371 to

λ5506 is common to the 1912 and 1913 investigations, but an entirely new series of plates was made for the common region. The Pasadena plates were taken by Mr. St. John and Mr. Babcock with the 30-foot plane spectrograph, using a remarkably fine grating by Anderson, which gives diffraction patterns of the most perfect symmetry in the case of sharp lines. The Mount Wilson plates made by Mr. St. John with the 75-foot spectrograph in conjunction with the 150-foot tower telescope, using a large Michelson grating, give excellent definition for both bright and dark lines. In both series the Pfund arc was used upon a 110-volt direct-current circuit. By employing a series of overlapping plates, the standards have been combined in various ways and are interlocked throughout the region investigated, thus yielding a very high degree of precision.

The pessimistic views of various observers as to the possibility of determining the position of standard lines to the third decimal place have led to a careful investigation of the structure of lines in various parts of the arc by Mr. St. John and Mr. Babcock. The preliminary results indicate that the main cause of the large discrepancies between the results of different observers is to be found in the unsymmetrical widening of the lines as the negative pole is approached. If comparison be made between these sensitive lines, when of equal breadth at the center of the arc and at the negative pole, the differences in wave-length are very slight, but these differences apparently increase enormously when the widened lines near the poles are measured. They have therefore discarded the use of a slit parallel to the axis of the arc, as used by other observers, substituting a slit placed at right angles to the axis of the arc at the middle point of an enlarged image. Under these circumstances the lines with a short slit have good edges and uniform width throughout their length, and quite consistent results can be obtained, even in the case of lines which have hitherto given the largest discrepancies.

The chief conclusions of the investigation are summarized at the beginning of this report.

Professor Störmer's Investigations on Solar Vortices.

As stated in the last annual report, Professor Carl Störmer, of the University of Christiania, came to Pasadena during the summer of 1912 as a Research Associate of the Carnegie Institution of Washington. Since his return to Christiania he has continued his theoretical investigations begun here, and has obtained very important results on the nature of the vortices in sun-spots.

The preliminary mathematical study of the subject led to the view that the hydrogen whirls of the flocculi are not real current lines, but lines of magnetic force due to a whirl at a lower level, hidden behind the upper layers of the sun's atmosphere. The cur-

rent lines of this hypothetical whirl would be logarithmic spirals tending more and more to become circles, according as the structure of the hydrogen whirl tended to be more nearly radial. Combining the results of the Director's investigations on the magnetic phenomena of sun-spots with the recent work of Mr. St. John on radial motion of the spot vapors, the conclusion is reached that the magnetic field is produced by the motion in the vortex of negatively charged particles. The current lines in this low-lying vortex are orthogonal to the spiral hydrogen flocculi, so that spectroheliograph plates furnish the means of determining the form of the current lines.

Proceeding in this way, Professor Störmer has calculated the magnetic field over a spot vortex. As observation shows that the intensity of the magnetic field decreases rapidly in passing upward, it becomes necessary to choose such dimensions of the vortex as make the results of the calculation harmonize with the observed facts. A discussion of the formulæ shows that if the thickness of the vortex is small compared with the diameter of the whirl, and if the inner diameter of the whirl is of the same magnitude as the thickness, then the magnetic force will decrease very rapidly along the axis, as found by the Zeeman effect. For example, if the thickness of the vortex is assumed to be 500 km., the inner diameter of the whirl 500 km., and the outer diameter 50,000 km., other probable assumptions as to the form of the current lines and the charge lead to the result that at the level just above the whirl the force is of the order observed by the Zeeman effect and decreases upwards so rapidly that it can hardly be detected at the level of the hydrogen flocculi.

A very striking resemblance appears if we compare the field of force projected in a meridian plane with spectroheliograph pictures of calcium prominences around a sun-spot at the sun's limb, such as those reproduced by Slocum in his paper on the attraction of sun-spots for prominences.

Professor Störmer is continuing the investigation and will soon present the detailed results for publication by the Carnegie Institution of Washington.

Ultra-violet Limit of the Solar Spectrum.

Mr. van Maanen began in July a series of photographs to determine whether the ultra-violet limit of the solar spectrum is subject to important variations in position. The solar spectrum is photographed once in about 10 days with a quartz spectrograph, used in connection with the Snow telescope. An iron-arc comparison spectrum is employed to give the wave-length of the limiting region, and a record is kept of the condition of the sky and of the mirrors. For the sun on the meridian the observed limits have been $\lambda\lambda$ 2973, 2970, and 2962, while with a solar altitude of 32° the limit came out λ 3006. By making the photographs with the sun at a given altitude

and averaging the results over a sufficient period to eliminate the effect of changes in the transparency of the sky and in the coefficient of reflection of the mirrors, it may be possible to determine whether considerable variations take place.

INVESTIGATIONS OF STARS AND NEBULÆ.

Observing Conditions.

During the year ending August 31, 1913, the 60-inch reflector was in operation 190 entire nights and during parts of 100 nights, while on 75 nights no observations could be made. The instrument was in use 2,383 hours out of a total of 3,605 hours of darkness, or 66.1 per cent of the total night time. There were 1,193 hours lost because of weather conditions and 29 hours on account of silvering the 60-inch mirror, which was done on October 19, 1912, April 16 and August 10, 1913. The statistics for each month are given in the following table, prepared by Mr. Hoge, night assistant.

Month.	Hours darkness.	Hours working.	Hours cloudy.	Hours silvering.	Work.		
					All night.	Part of night.	None.
1912.							
September	295	261	34	....	22	6	2
October	331	220	99	12	16	9	7
November	333	226	107	....	16	8	6
December	346	201	145	....	13	11	7
1913.							
January	346	177	169	....	12	10	9
February	308	142	166	....	10	6	12
March	324	207	117	....	16	8	7
April	286	165	112	9	16	3	9
May	270	205	65	....	17	10	4
June	240	185	55	....	17	10	3
July	255	188	67	....	16	12	3
August	271	206	57	8	19	7	6
Totals	3,605	2,383	1,193	29	190	100	75

Since June 1, 1913, an exact record has been kept of the actual times that exposures were in progress, showing a total for 3 months of 407 hours and 15 minutes, or 70 per cent of the time the instrument was in use. In other words, 30 per cent of the working-time was required for making settings, changing plates, picking up guiding stars, focusing, and making such adjustments as are incidental to the work. The amount of time necessary between exposures varies much with the nature of the observations, the Cassegrain spectrograph requiring from 5 to 11 minutes, while direct photography involves much longer intervals, on account of the careful knife-edge focusing, the necessity of finding suitable guiding stars, the change of diaphragms in photometric work, etc.

The conditions for observation were in general perhaps somewhat below the normal for Mount Wilson. A record of the seeing, on a scale of 1 to 5 (the latter being perfect) is shown herewith, together with the wind-record from Mr. Hoge's personal observations.

The observations show 10 per cent high winds, 33 per cent brisk and moderate, and 57 per cent light to calm.

Seeing.	Nights.	Wind.	Nights.
<1 to 1	50	Very high	10
1 to 2	70	High	25
2 to 3	123	Brisk	48
3 to 4	44	Moderate	70
		Light	113
		Calm	89

The outer dome-covering of sheet-iron, substituted for the canvas covering formerly used, was completed in the spring of 1913 and has proved effective in keeping down the temperature within the building during the hot weather. The highest temperature recorded was 29°.9 C. on July 11, while the lowest was −8°.0 C. on January 5.

Direct Photography.

In continuation of his photographic work on nebulæ and star clusters with the 60-inch reflector, Mr. Pease has obtained photographs of the following objects in the principal focus of this instrument:

Spiral nebulæ: *N. G. C.* 205, 278, 1023, 2403, 2681, 2976, 3593, 4216, 4900, 5383, 5857–9, 5907, 6217.
Spindle nebula: *N. G. C.* 5308.
Planetary nebulæ: *N G. C.* 1501, 1535, 2022, 2392, 7662.
Irregular nebulæ: *N. G. C.* 650, 1555, 4449.
Globular clusters: *N. G. C.* 6093, 6218.

Other objects also photographed in the principal focus include *Nova Geminorum*, the region of Encke's comet, and the regions *SU Draconis* and *SW Draconis*.

The following objects have been photographed with the Cassegrain combination of 100-feet equivalent focal length:

Planetary nebulæ: *N. G. C.* 1535, 6095, 7026, 7027.
Also the star *B. D.* +30° 3639, found by Campbell's spectroscopic observations to have a hydrogen envelope.

Miss Van Deusen has counted the stars on photographs of the cluster *Messier* 13, made by Mr. Pease with exposures ranging from 6 minutes to 37.5 minutes. Counts were made in two directions at right angles to one another and the results here given are the means of the two. These results are only preliminary and will doubtless be somewhat modified with increased experience in counting.

Exposure.	No. of stars.
Min.	
6	5,813
15	7,728
37.5	18,424

Stellar Parallaxes.

Mr. van Maanen has begun a series of photographs with the 60-inch reflector to determine whether satisfactory measurements of stellar parallaxes can be made with the 80-foot-focus Cassegrain combination. This work is still in its preliminary stages and none of the plates have yet been completely measured.

Stellar Photometry.

The observational part of the investigations in stellar photometry by Mr. Seares includes 455 photographs, all made with the 60-inch reflector and distributed as follows: *RR Draconis*, 16; brighter stars of the North Polar Sequence, 175; Selected Areas, 199; miscellaneous, 65. The last group includes, among others, plates taken at the request of Professor Pickering, Professor Charlier, and Dr. Schlesinger.

RR DRACONIS.

The photographs of the *Algol* variable *RR Draconis* were made in part with color-sensitive plates and a yellow filter adjusted to give approximately visual magnitudes. The comparison of these "photovisual" results with the ordinary photographic magnitudes shows an increase in the color index as the variable approaches its minimum. During minimum the index exceeds that corresponding to normal light by 0.57 mag. The light of the faint star is only 3 per cent of the total radiated, and since the eclipse is total, the change in color is a measure of the difference in the spectral types of the two components, the probable values being A2 and F5, respectively. The increase in redness as the minimum is approached is in agreement with what would be expected from the fact that the fainter object is much the larger of the two, but raises an interesting question as to the relation between spectrum and density. Although the darker star is the larger, its density is probably less than that of the bright object. If the ordinary relations between spectrum and color index apply, we have apparently an advanced spectrum associated with a relatively low density.

NORTH POLAR SEQUENCE.

The observations are a continuation of those previously reported, and are concerned with the determination of the photographic scale for the stars brighter than magnitude 10.5. The magnitudes previously found for the objects between 10.5 and 15.5 are in excellent agreement with the results derived at the Harvard Observatory. The scale for this region was accordingly assumed to be accurately known, and the further observations were arranged in such a way as to establish for the bright stars a scale which should be homogeneous with that assumed as the basis of the investigation. Each bright star was photographed upon the same plate with a group of faint stars, the full aperture of 60 inches being used for the latter, and for the former, diaphragms and screens producing an apparent brightness falling within the limits of the adopted scale. The subtraction of the reduction constant of the diaphragm or screen from the observed apparent magnitude gave the required magnitude of the bright star. All magnitudes determined with the same diaphragm or screen are affected equally by the error in the reduction constant, and hence the scale should be homogeneous with that adopted for the

fainter objects. The use of several different combinations of screens and diaphragms afforded a number of independent determinations of the scale, and gave results which show that the reduction constants are correct within a few hundredths of a magnitude. The separate scales are in good agreement, but show in each instance a considerable divergence from the Harvard results. Combining the results for the bright stars with those previously found for the faint stars, the difference between Mount Wilson and Harvard is approximately as follows:

$$\text{Mt. W.} - \text{H.} = +0^{m}.37 - 0^{m}.070\,(11.0 - \text{M})$$

Both scales are referred to the international zero-point. The comparison covers magnitudes 2.0 to 15.5, but for $M > 10$ the last term of the formula is to be disregarded.

PHOTOGRAPHIC MAGNITUDES FOR THE SELECTED AREAS.

The photographs of the Selected Areas form a part of a program which has for its purpose the determination of standards of magnitude for faint stars in each of the areas on and north of the celestial equator. In order that comparisons may be made with other investigations, the brighter stars will be included, and to this end it is proposed to establish the photographic scale for each area over an interval whose magnitude limits will be approximately 8.5 and 17.0. The investigation will be limited to stars within 10′ of the central star of each area. The relative magnitudes are to be determined by means of exposures with diaphragms and a wire-gauze screen. The arrangement of plates and exposures for each area is shown herewith. The results will be reduced to the international zero-point by inter-comparison and by comparisons with the Pole. Of the 460 photographs required for the relative magnitudes, 199 have been obtained. Each plate will be measured twice. The measurement of 95 plates has been completed and 22 others have been measured once. The reductions are well advanced.

No. of plates.	Apertures.	Exposure time.
		Min.
1	60, 32, 32, 60	15
1	60, screen, screen, 60	15
2	60, 32, 14, 9, 9, 14, 32, 60	2

BRIGHTNESS OF THE NIGHT SKY.

Mr. van Rhyn has made a series of measures of the brightness of the sky at night with the photometer described in Publication No. 22 of the Astronomical Laboratory of Groningen. The results, in harmony with those of Abbot and Yntema, indicate that the brightness of the background of the sky is not due exclusively to direct starlight. Assuming the value of the starlight for the higher galactic latitudes given by the Groningen observations, Mr. van Rhyn has sought to measure the brightness of star light in the Milky Way

and the variations of the so-called earth light with zenith distance, azimuth, and time. The preliminary reductions are promising, but further observations of the earth light are needed before the brightness of the starlight in the Milky Way can be determined definitely.

Stellar Spectroscopy.

INSTRUMENTS.

Most of the stellar spectroscopic observations of the past year have been made with the Cassegrain spectrograph at the 80-foot focus of the 60-inch reflector. For stars brighter than magnitude 6.5, a 64° prism with a camera of 102 cm. focal length has been used, and for fainter stars the same prism with a 45.7 cm. camera. Recently a prism of 39° angle was completed in the optical shop, and preliminary tests with this prism and a triple camera objective of 45.7 cm. focal length indicate that spectra of stars of magnitude 9.5 may be obtained with an exposure time of about 2.5 hours. The scale of the photographs is sufficient to enable excellent classification as well as to provide approximate radial velocities.

During the year two new spectrographs designed for special observational work have been completed. One of these is a concave-grating spectrograph having a grating of 1 m. radius. It is designed so that it may be used in either the first or second order and with or without a collimating lens to remove astigmatism. It is planned to use this instrument in the detailed study of certain special types of stellar spectra.

The second instrument is a very small spectrograph planned for work on extremely faint stars and nebulæ, at the primary focus of the telescope. It consists of a 60° ultra-violet glass prism used in conjunction with camera and collimating lenses of 27 mm. aperture and 136 mm. focal length. The spectrograph fits directly into the plate-holder opening and the guiding is carried on in the same way as for direct photography, by moving the spectrograph on the double slides by means of the guiding screws. This instrument has been employed by Mr. Pease in the photography of the spectra of several faint stars and nebulæ.

RADIAL VELOCITIES.

The program of work during the year has consisted mainly of a continuation of the determination of the radial velocities of the two lists of stars already under observation last year. The first is made up of stars having spectra of types A and B, a knowledge of whose velocities is of especial importance for the investigations by Professor Kapteyn upon star-groups and star-streaming. The second list consists of stars of large proper motion for which the parallaxes have been determined. A knowledge of the radial velocities of these stars

provides the means for the determination of their absolute motion in space. Their spectra in general are of types F to M.

In addition to these two main lists a few photographs have been obtained of the spectra of stars of type N (Secchi's Type IV) preliminary to a study by Mr. van Maanen of the spectra of these stars and a determination of their radial velocities. Mr. van Rhyn has also employed the Cassegrain spectrograph in the determination of the spectral classification of certain stars with a view to selecting such as are best adapted for the study of some problems relating to the absorption of light in space. On a few of his negatives the spectra of two stars having as nearly as possible identical spectra have been photographed side by side, one star having a large and the other a small proper motion.

The observational work has been carried on by Mr. Adams, Mr. Kohlschütter, Mr. Whitney, and (during Mr. Kohlschütter's absence) Mr. van Maanen. Miss Lasby has also assisted in a part of the observations. A summary of the observations for the year September 1, 1912, to September 1, 1913, follows:

Spectrograms of stars types A, B, and Oe	788
Spectrograms of stars types F to M	258
Spectrograms of stars type N	10
Spectrograms of *Nova Geminorum* No. 2	5
Total number of spectrograms	1,061

The use of reduction tables has enabled the department to make rapid progress in the measurement and reduction of this large amount of observational material, and at present two, and in many cases three, independent sets of determinations of the radial velocity are available for each photograph. This part of the work has been carried on by Miss Lasby, Miss Burwell, and Miss Ensign, of the Computing Division, and by Mr. Adams and Mr. Kohlschütter. Miss Shumway has assisted in the reduction of the measures.

Some of the principal results of the radial-velocity work may be summarized as follows:

(1) The total number of stars of types B and A for which three or more determinations of the radial velocity are available and which have constant velocities is 245. These stars are for the most part between the magnitudes 5.0 and 6.5 on the Harvard scale.

(2) The total number of spectroscopic binaries of types B and A (so far found) is 99. A considerable number of additional stars show variations which are probably real. In view of the difficult character of their spectra, however, additional observations are required to establish their variation.

(3) The radial velocities of 18 stars between magnitudes 5.5 and 7.2 having spectra of types F8 to Mb and small proper motions have been determined from three or more observations.

(4) The radial velocities of 95 stars with measured parallaxes have been obtained. These stars all have large proper motions and are for the most part of the spectral types F to M. Their magnitudes range from 5.5 to 8.2. The absolute motions in space for 61 of these stars have been calculated, and although the resulting velocities are, of course, much affected by the errors in the determinations of the parallaxes, it may be of interest to note the result shown in the accompanying table.

No. of stars.	Absolute velocity.
	km.
11	100 to 200
4	200 300
5	>300

A velocity of 590 km. is found for the star *Lacaille* 8381, but it seems probable that the measured parallax of this star is too small.

(5) Observations of a number of stars in the *h* and χ *Persei* clusters show that a considerable number of these stars are moving with the same radial velocity and in all probability form a group. Of a total of 14 stars observed, 9 have the same radial velocity within the limits of errors of measurement. Their spectra are all of types B and A. Of the stars which do not belong to the group, three are of types F to K and the other two lie at a considerable distance from the mean positions of the stars forming the group. The average velocity of the nine stars is −43 km., an exceptionally high value for stars having this type of spectrum.

NOVA GEMINORUM NO. 2.

Observations of the spectrum of *Nova Geminorum* No. 2 during the year have led to the following conclusions:

(*a*) The bright bands show the presence of marked absorption on the latest photographs taken in April 1913. This is over 13 months after the discovery of the *Nova*. All of the bright bands have the same characteristics of structure.

(*b*) There have been no marked changes in the widths or the displacements of the bright bands since they became a prominent feature of the star's spectrum. The average displacement of the principal bands on the negative of April 1913 was about 1.0 Å toward the red.

(*c*) The hydrogen band at λ4686 has shown some remarkable fluctuations in intensity. A sudden change in the brightness of the star between November 15 and 17, 1912, observed by Professor Barnard, is probably due mainly to the variation of this line. In view of Professor Fowler's recent discovery of this line in the laboratory and his observations of its variations with differences in the relative amounts of hydrogen and helium present in a mixture, the variations of this line in the *Nova* spectrum are of peculiar interest.

COMPANION OF RIGEL.

Observations of the spectrum of the companion of *Rigel* (β *Orionis*), magnitude about 6.8, show that this faint star has a spectrum nearly identical with that of the principal star, which is about seven mag-

nitudes brighter. The mean of a few measures of its radial velocity gives a value almost identical with that of the larger star, thus making the physical connection of the two practically certain. The radial velocity of the fainter star may be subject to a small variation, although the fact that it is a very close visual binary complicates observations of its velocity.

CLASSIFICATION OF SPECTRA.

The classification of the spectra has been continued regularly in connection with the measurement, for the most part by Mr. Kohlschütter. The results for about 300 stars of types A and B were communicated to Professor Pickering and have been employed by him in a comparison of the relative advantages for classification purposes of spectra obtained with slit spectrographs and with the objective prism. The spectral classification of the stars with measured parallaxes has also been thoroughly revised and has proved of great value in an investigation of the luminosity curve of K-type stars now being completed by Mr. Kohlschutter. In this connection he is giving considerable attention to the possibility of finding in the relative intensities of certain spectral lines criteria bearing on the absolute luminosities of stars. The recognition of the important applications of the registering micro-photometer devised by Professor Koch to the determination of the intensities of spectral lines is leading to a study of additional lines to be used for classification purposes on the basis of their absolute intensities.

SPECTRA OF STARS IN THE HERCULES CLUSTER M 13.

Two photographs of the spectrum of the *Hercules* cluster *Messier* 13 have been obtained by Mr. Pease with the new focal-plane spectrograph. The first plate had an exposure of 21 hours with the slit set at a distance of 11″ south of the center of the cluster. The second had an exposure of 22 hours with the slit 18″ north of the center. The direction of the slit was east and west for both photographs and its width was 0.025 mm. for the first plate and 0.050 mm. for the second. The guiding was as accurate as possible throughout and as a result the spectra of the individual stars are separated clearly. Of these it has been possible to classify 6 on the first photograph and 13 on the second, a total of 19 separate stars. The spectra are divided as follows, taking as the unit five divisions of the Harvard scale:

A 0	2
A 5	5
F 0	2
F 5	8
G 0	2

It is clear from these results that no satisfactory conclusions as to the spectra of the stars in globular clusters can be drawn from photographs of their integrated light.

SPECTRA OF NEBULÆ.

Mr. Pease has also photographed with the same spectrograph the spectra of the planetary nebulæ *N. G. C.* 6210, 6543, and 7009, and two points in the irregular nebula *N. G. C.* 7023.

PROFESSOR KAPTEYN'S INVESTIGATIONS.

Professor Kapteyn has devoted most of his attention to a further study of the helium and early A stars. During the last two or three years the work has necessarily been of a preliminary character. In consequence of this fact the accounts which have appeared from time to time* have also been simply preliminary communications. Now that observations for radial velocities of the helium and A stars at the Mt. Wilson Solar Observatory are nearing completion, it is intended to bring these investigations to a more or less definitive close.

A first paper, which is almost ready for press, will treat of the helium stars in Boss's "Preliminary Catalogue," between galactic latitudes ±30° and longitudes 217° to 360°. Their number is 319, which is about half of all the helium stars between these latitudes and somewhat over 42 per cent of the helium stars in Boss's catalogue. Fourteen of these stars seem to belong to a separate group—the *Vela* group—and one probably to the second stream. With few exceptions—mostly near the limits—all the rest apparently belong to a single group. Considerable care was taken to put this point beyond reasonable doubt. Of the 304 stars, 21 were finally considered as exceptions and were consequently rejected. Of course there remains some doubt whether a few other stars ought not to be counted as members of the group, but such uncertainty seems unavoidable.

For each of the 283 stars admitted to the group the parallax was derived by a method similar to that employed by several astronomers for the members of the *Vela* group and the *Hyades*. The probable errors for each of these parallaxes were also computed. In general the accuracy is satisfactory and a first attempt to draw up a star-map, showing the positions of the stars in space, thus appeared to be justified. As the publication of the paper will soon follow, further particulars need not be given here.

At the request of the Director a short paper has been prepared, bringing together, in the briefest possible space, the evidence we possess at present as to the reality of the two following phenomena:

(*a*) On the average the fainter stars are redder than those that are brighter.

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*On the Systematic Proper Motions of the *Orion* Stars (Transactions of the International Union for Coöperation in Solar Research, 3, 215, 1910). Een paar nieuwere onderzoekingen op het gebied der evolutie van de vaste sterren en het sterrenstelsel (Address before the Congress of Physicists and Physicians in the Netherlands, April 1911). The Milky Way and the Star-Streams (Meeting of the Academy of Sciences in Amsterdam, December 1911). Star Systems and the Milky Way (Meeting of the Academy of Sciences in Amsterdam, February 1912). On the Structure of the Universe (Address before the National Academy of Sciences at Washington, April 1913.)

(*b*) Apparent magnitudes and spectral lines being the same, the stars are redder the farther away they are.

If these phenomena are real, as the existing evidence strongly indicates, their importance can hardly be overestimated, whatever be their explanation. The evidence seems to show that the effect, though small for the brighter stars, becomes far greater for the very faint ones. The quantitative investigation can thus be undertaken to the best advantage with the most powerful instruments. It must embrace not only the definitive establishment (or refutation) of the observed facts (*a*) and (*b*), but also—in case of confirmation—the determination of the question as to which of the possible explanations is the true one.

Professor Kapteyn and Mr. Kohlschütter have also undertaken the investigation of the luminosity curve for stars of each of the spectral types F, G, K, M. For the B and A stars such a determination will form part of Professor Kapteyn's study of these stars. In fact, for the B 0–B 5 stars the luminosity curve will be given in the paper alluded to above. For the F, G, K, and M stars, however, another method must be employed. The great increase in the data for parallax, together with the excellent data for proper motion at present available through Boss's "Preliminary Catalogue," offers good promise for a successful treatment of the question. A preliminary solution for the K stars has already been obtained. The work is meant as a first step in the investigation of the arrangement of stars in space, for each spectral class separately—the most urgent problem at the present time in the study of the structure of the universe. Of course a reliable solution of the whole problem will not be possible before much fainter stars than are now available can be included. It is hoped that this preliminary work will greatly help further study, by aiding the observer in deciding as to the kind of observations and the selection of objects required for a future successful treatment of the problem.

Absorption in Space.

Mr. van Rhyn began in December a series of observations with the 60-inch reflector for the purpose of determining whether the fainter stars are redder than the brighter ones. Regions surrounding a bright star with known color index are photographed in the principal focus on an ordinary Seed "27" plate and on a Cramer isochromatic plate with a yellow filter, the latter combination giving approximately a visual intensity curve. The intensity of the bright star was artificially reduced about 8 magnitudes by means of a diaphragm and a rotating sector. This reduced intensity gives the zero-point for both photographic and photovisual magnitudes. The scale was established by taking on every plate two exposures of the same duration, one with a full aperture, the other with a 32-inch diaphragm.

The color index is given by the differences between the photographic and the photovisual magnitudes.

The measures and reductions already completed indicate that the method should give satisfactory determinations of color differences, which will serve for the study of the problem of absorption of light in space. Professor Hertzsprung's results in the same field, obtained with the aid of a large objective grating, are described in the following section.

Professor Hertzsprung's Investigations.

In the last annual report an account was given of the observations undertaken by Professor Ejnar Hertzsprung, of the Astrophysical Observatory of Potsdam, who spent four months on Mount Wilson for the purpose of determining the effective wave-lengths of the light of faint stars. Since his return to Europe Professor Hertzsprung has measured and completely reduced the plates he obtained last year with the 60-inch reflector for the region containing the cluster *N. G. C.* 1647. The remaining regions will be investigated as soon as a suitable measuring-machine becomes available.

Twelve plates of *N. G. C.* 1647 were measured in Professor Kapteyn's laboratory during a visit of Professor Hertzsprung to Groningen. Half of them are Lumière "Sigma," the other half Seed "27" plates. The times of exposure range from 6 seconds to 30 minutes, in order that the same star may show images of widely differing intensities, thus enabling the observer to reduce all the measured wave-lengths to the same intensity of image.

For obvious reasons the effective wave-lengths are found to be much more precise for the brighter stars than for the fainter ones. Over 200 stars were measured. For the 50 brightest the mean error is on the average about ±8 Å, corresponding to ±0.04 magnitude in the difference between photographic and visual magnitudes (color index). The resulting effective wave-lengths show a very systematic change with apparent magnitude, in the direction indicating that the fainter stars are redder than the brighter ones. The Lumière "Sigma" and Seed "27" plates agree closely in making the change about 20 Å for each magnitude. There is only a single faint star (mag. 12.4) which appears decidedly white.

The phenomenon may be due in part to the fact that the bulk of the stars belong to a single physical group. For such a group analogy with other known cases would lead us to expect increasing redness with decreasing absolute brightness. On the other hand, many of the stars can not belong to such an assumed group. We thus have a strong indication either that in the region considered there is but one star which is certainly of the first type or that the color of the stars is due to selective absorption in space (?).

PHYSICAL LABORATORY.

Instruments.

Additions to the laboratory equipment include a 4-inch plane grating of exceptionally fine quality, ruled by Dr. Anderson on Rowland's machine, and a number of accessories for the 30-foot spectrograph. A set of three 500-volt generators provides a higher direct-current voltage than was formerly available. The vertical spectrograph for the 15-foot concave grating has been completed in the instrument shop and is now being mounted in the laboratory, where it will usefully supplement the plane-grating instrument in certain classes of work.

Tests have been made in coöperation with Professor Koch on the availability of the registering micro-photometer for the measurement of line intensities in photographs of the Zeeman effect, furnace, and tube-arc spectra. The results are so satisfactory that the method will be generally employed in the laboratory work.

In connection with his investigations of the Zeeman effect, Mr. Babcock has made a critical examination of the performance of the 30-foot spectrograph, involving a careful test of the 8-inch photographic lens and resolving power tests on the 8-inch Michelson grating. The color curve of the lens was first examined as carefully as possible, and a large plane mirror, known to be flat to one-twentieth of a wave, was then placed below it. An examination of the diffraction pattern for pinhole and slit sources led to the following conclusions: On the axis the whole lens is practically perfect; for work off the axis the performance is improved by stopping down the aperture to 6 inches; for actual use in the spectrograph, an inclination of the lens sufficient to throw the reflection from its surface off the photographic plate involves a serious sacrifice in definition. These reflections do no harm in ordinary arc and furnace work, but are troublesome when the sun is used; in case of need they can be practically eliminated with the loss of a small amount of light. Tests of the Michelson grating with the absorption spectrum of iodine gave about 90 per cent of theoretical resolving power in the third order spectrum when the area of the grating is cut down to 15 cm. by 5.5 cm.

Mr. Babcock has also determined the color curves for the visual and photographic objectives of 13 feet focal length, and has prepared a chart which makes a selection of the proper slit-width for any given purpose extremely easy and rapid. A test was also made of a large Zeiss prism in the 13-foot spectrograph, in the hope that in the green and yellow the prism would prove much faster than the second order of the Anderson grating, thus aiding in the study of the Zeeman effect for very weak lines. It was found, however, that the intrinsic brightness of the second order grating spectrum is about the same as that of the prism and the latter was therefore rejected for the present purpose.

Miscellaneous work on instruments by Mr. Babcock has included a determination of the variation of field-strength with pole-gap and with magnetizing current for the large Weiss electro-magnet, and the preparation of curves showing the effect; a study of the Leeds & Northrop synchronizing fork for constant angular velocities, in the hope that it might be used to control the driving mechanism of the 100-inch reflector; the testing of a 1:1000 alcoholic solution of pinacyanol five years old for sensitizing action, which proved to be unimpaired; and the remounting of the Werlein compound quarter-wave plate, which had been injured by long exposure to the solar image in the study of the sun's general magnetic field.

Electric-Furnace Spectra.

The work of Mr. King in the Pasadena laboratory has been a continuation of the study of spectra produced at various temperatures of the electric furnace, together with other experimental work closely related to this investigation.

In the last annual report, the leading features of electric-furnace spectra were summarized, sufficient material being then on hand to indicate the general phenomena presented by the spectrum of this source. During the past year the results for the visible portion of the iron spectrum have been published, and a similar paper for the spectrum of titanium is in press. The region of spectrum studied for each element extends from λ 3880 to λ 7400, the number of lines examined being 512 for iron and 625 for titanium. The range of furnace temperature employed was from 1800° C. to above 2600° C. Within this range, three stages of temperature have been chosen, designated as low, medium, and high, the spectra for which show decided differences. The lines are then divided into five main classes, according to the temperature at which they appear and the rate of growth in intensity as the temperature increases. A comparison has also been made between the arc spectrum and the spectra given by the furnace at different temperatures. This promises to furnish much evidence, as the material becomes more extensive, on the relation between these two sources, the spectra of which show many striking differences. In the case of iron, a comparison between the furnace spectra and data published on flame spectra has shown how the various flames are probably related as to effective temperatures in producing radiation. The titanium spectrum shows a noteworthy richness in lines in spite of the high melting-point of this substance. A temperature of 2600° C. gives practically all lines shown by the arc except enhanced lines, and the stronger among even these may be photographed by prolonged exposure.

The variations in furnace radiation with wave-length have been studied by means of a small concave-grating spectrograph. The red end of the spectrum for both iron and titanium is found to require a higher temperature for its production than the blue region,

where many low-temperature lines are observed. The distribution of line intensities through the visible spectrum bears little resemblance to the intensity gradation observed for the spectrum of an incandescent solid, though the extension of the spectrum into the ultra-violet increases with the temperature.

An important class of furnace lines is found to be relatively much weaker in the arc spectrum. For titanium, most of the lines of this class appear at temperatures from 2300° C. to 2600° C., being absent or faint at lower temperature and weak in the arc. They thus appear especially sensitive to a certain degree of excitation, for which the furnace is most suitable.

The furnace, as regularly operated in a partial vacuum, is found to give only the line spectrum for titanium, the bands given by the arc in air not appearing in the furnace. This affords additional evidence that the banded spectrum is due to titanium oxide.

"TUBE-ARC" SPECTRA.

Some experiments by Mr. King with thin-walled tubes forced to a high temperature led to the development of a new form of arc, the spectrum of which shows many interesting peculiarities. The horizontal graphite tube used in the furnace chamber was heated to high incandescence and made to burn apart, an arc forming between the ends which carried for a short time a current of about 800 amperes at a potential of 30 volts. This "tube-arc" is essentially a high-current vacuum arc inclosing a mass of luminous vapor somewhat removed from the direct path of the current between the ends of the broken tube. The spectrum is very different from that of the furnace and of the ordinary arc in air, the most striking feature being the great strength of the enhanced lines, which usually require the spark discharge to show them strongly. In this case these lines appear in a low-potential arc, and, further, have been found to be strongest near the center of the tube's cross-section, away from the direct path of the arc. In addition to the enhanced lines of metals, the tube-arc gives with great brilliancy the hydrogen lines from $H\alpha$ to $H\epsilon$ and the entire line spectrum of carbon. The structure of the important spark line λ 4481 of magnesium is better defined than in any other source in which it has been examined. The line was found to be double, and the evidence is against this being caused by reversal. The pair of lines which make up λ4481 has been measured, the violet line being about twice as strong as the red.

When the image of the luminous interior of the tube-arc was projected on the slit of the plane-grating spectrograph, interesting variations were observed in the strength of the lines of different elements between the center and wall of the tube. This led to an extended series of experiments, in the course of which lines of hydrogen, carbon, titanium, vanadium, iron, chromium, silicon, tin, calcium, strontium, and barium were examined. A region near the

center of the tube-arc was found to give a maximum intensity for the lines most characteristic of the spark discharge, such as those of hydrogen and carbon. The effect points to a distinct physical difference in the conditions for the production of enhanced and non-enhanced lines. Each of the elements showed a definite behavior in the degree to which its spectrum lines were favored by the radiation of this central region, and it was possible to classify the elements studied, dividing them into groups on this basis.

A general but somewhat variable tendency toward dissymmetry was observed in the structure of tube-arc lines. This is not noticeable for the enhanced lines, but the majority of the wider arc lines show a greater strength on the red side, giving strong dissymmetry in the case of many reversed lines. This effect increases in the part of the tube-arc where the enhanced lines are strongest and seems to be similar in nature to the dissymmetry often given by the spark discharge.

A comparison of these results for the tube-arc with the known phenomena of arc, spark, and furnace spectra shows that the effects may be unified by a consideration of the electro-luminescence which should be present as a result of the ejection of corpuscles from the highly heated carbon, the resultant effect of which may be expected to reach a maximum in the portion of the tube-arc which emits enhanced lines most strongly.

Effect of Pressure on Ionization.

A series of experiments was made by Mr. King on ionization effects at various pressures, which bears on solar phenomena as well as on those of the furnace and tube-arc radiation. When two insulated carbon electrodes were supported within the heated furnace tube, according to the method of Harker, the negative electricity passing from the hotter to the cooler electrode gave currents of about 1.5 amperes for a low pressure. As the pressure increased, the ionization current fell rapidly until a pressure of 4 atmospheres was reached, after which the change was slower, but a measurable current persisted for as high as 20 atmospheres. These experiments showed the magnitude at higher pressures of the effects which were known to exist in vacuum and at atmospheric pressure.

Analytical Study of Arc Spectra.

Mr. St. John and Mr. Babcock have begun an investigation of the spectrum of different parts of the iron arc, with special reference to the availability of lines as standards. Two series of photographs are now awaiting reduction, namely, one in which no slit was used, a minified image of the arc being focused in the plane usually occupied by the slit, and a second with the slit, in which light from a point very close to the negative pole was compared with light from the center of the arc. Important results have been obtained from the few plates

of this last series which have been measured, the lines of the negative pole showing shifts to red and violet according to their classification under pressure by Gale and Adams, though the magnitudes of the displacements plainly indicate the effect of some cause other than pressure alone. Many lines, which are sharp and narrow in the center of the arc, show great widening and lack of symmetry at the negative pole, and nearly all lines show an increase in intensity there. In the majority of cases this increase is probably about fourfold. This last series includes at present 77 photographs, covering the spectrum of iron from λ 3500 to λ 6500. It is to be extended to include comparisons between the positive pole and the center of the arc, together with other features which may be found of interest. The series of monochromatic images includes about 100 photographs covering the region λ 4500 to λ 5500. The spectroheliograph was tried for this work, but the arc could not be held steady enough to get good results.

During the year Mr. Babcock has also made a number of photographs of secondary standards in the iron arc for Mr. St. John, and some comparison photographs of the silicon spark and the iron arc, using for the latter the concave-grating spectrograph of 1 m. focal length belonging to the laboratory.

Zeeman Effect.

Mr. Babcock has taken 153 photographs of spectra for the study of the Zeeman effect during the year. About 25 of these were made with short exposures for a determination of the magnetization of the large magnet, and about 60 were obtained for the study of the three strong chromium lines λ 4254, λ 4275, and λ 4290. The remainder of the plates were divided between iron, chromium, vanadium, and nickel, which are now being measured.

The wave-lengths of the three chromium lines in the arc, the spark, and the spark in magnetic fields have been measured with results shown herewith. The wave-lengths were taken from impurity lines of chromium occurring in the iron arc. An examination of these lines in a very intense magnetic field led to the discovery that λ 4254 has 21 components—apparently the largest number hitherto found in the study of the Zeeman effect. Under certain conditions three of these components reverse, giving an appearance of 24 components.

Arc.	Spark.	Mean of all components in magnetic field of 28,500 gausses.
4254.340	.335	.348
4274.801	.796	.810
4289.722	.718	.733

In connection with the Director's investigation of the general magnetic field of the sun much time has been devoted to observations, both visual and photographic, on certain weak lines found to show displacements on the sun. The visual observations were made with a concave grating of 1 m. focal length, mounted in the grating stellar spectrograph of the 60-inch reflector. The most interesting

and troublesome line investigated was λ5929.898, attributed by Rowland to iron. Mr. Babcock has never been able to identify this line in the spark, but has finally satisfied himself that it exists in certain parts of the iron arc of the Pfund type, where it is seen most easily very close to the negative pole, in coincidence with what appears to be an oxide line.

Horseshoe Vortices.

Dr. Anderson has made some interesting investigations on horseshoe vortices in liquids, in connection with the study of bipolar sunspots. A horseshoe vortex, developed in a tank of water by dipping a semicircular plate of sheet metal into the liquid and quickly removing it, travels in a straight line across the tank. On meeting centrally a vertical plate of glass immersed in the liquid, with its plane corresponding with the direction of motion of the vortex, the two halves of the vortex, though divided by the plate, pursue their courses without interruption. If one-half of the vortex be intercepted by a second sheet of glass, standing at right angles with the first, and joining it to the wall of the tank, the other half continues its motion to the end of the glass sheet, where it suddenly develops an extension to the surface of the liquid, thus returning to the horseshoe form.

Professor Koch's Registering Micro-Photometer.

The registering micro-photometer devised by Professor Koch and described in "Annalen der Physik," 39, 705, 1912, was brought from Munich to Pasadena early in August and mounted in the basement of the office building for the purpose of determining its applicability to the study of solar, stellar, and laboratory spectra.

The spectrum photograph to be investigated is mounted on the moving stage of a microscope, whose objective projects an enlarged image of the spectrum upon a narrow slit placed in the upper focal plane. The ocular of the microscope is replaced by a photo-electric cell connected with a string electrometer. As the image moves across the slit the variation in the intensity of the illumination of the photo-electric cell causes corresponding fluctuations in the charge of the electrometer and in the position of the string. An image of the latter is projected upon a second slit placed immediately in front of a moving photographic plate. The slit is perpendicular to the string and to the direction of motion of the plate. The instrument thus automatically registers upon the plate a curve showing the intensity distribution of the lines of the spectrum examined. With Professor Koch's instrument the scale of the curve may be either 7 or 46 times that of the original spectrum. The practically instantaneous response of the photo-electric cell and the high sensibility of the electrometer make it possible to record with precision the variations of density in the photograph.

Perhaps the point of greatest interest in connection with the instrument is the possibility it affords of eliminating personal errors from the measurement of the positions of spectrum lines. Owing to the fact that the existing instrument was constructed for photometric uses rather than for the precise measurement of positions, it has not been possible to test this feature fully. This much appears certain, however: Under favorable conditions the maximum of the registered curve representing a spectrum line may be determined with a precision corresponding to a few tenths of a micron on the original negative. Among the lines actually tested are several of those observed for the determination of the sun's general magnetic field, whose width and diffuseness render measurement by the usual method extremely difficult. Favorable results were also obtained from lines of stellar spectra too diffuse for measurement by the ordinary methods. In fact, wide lines give results superior to those from lines narrow and sharp, for a wider slit can be used in front of the photo-electric cell, with the result that irregularities in the curve caused by abnormal distribution of silver grains are greatly reduced. The same end may naturally be accomplished by lengthening the slit, but with narrow stellar spectra this can be done only to a limited extent. The results indicate that the only obstacle in the way of a substantial gain in the precision of spectrum measurements is the construction of a suitable mechanism for driving the microscope stage and the photographic plate at uniform speeds. An ultimate precision of one micron seems easily possible.

Although the test of the instrument for the measurement of the positions of spectrum lines is incomplete, it has been possible to investigate with some detail its applicability to the study of intensity distribution. It has been extensively used for this purpose in connection with lines in various classes of spectra, including sun-spot and normal solar spectra, spectra of *Arcturus* and *Nova Geminorum* No. 2, of the tube-arc, and of other terrestrial sources under varying conditions of pressure, magnetic field, etc. The results for lines showing complicated Zeeman structure are very interesting and suggestive. The fidelity with which the apparatus reproduces minute variations in photographic density as shown by successive registrations of the same line or spectrum is remarkable. A highly important feature is the revelation it affords of the part played by physiological error in the ordinary examination of spectra—lines apparently separated are shown, for example, actually to be blends, the separation being a contrast effect.

Finally, preliminary experiments have been made in the direction of adapting the instrument to the measurement of the total amount of silver deposited in star images, with the idea of applying it to stellar photometric investigations. The advantages of such a method

of measurement are obvious, for it affords a means of overcoming the most serious difficulty arising from bad seeing and, probably to some extent, that caused by any abnormality of the images, whether it be the result of imperfect guiding, or of aberrations or temperature deformations of the optical system.

Investigation of the Photographic Process.

Mr. Seares has presented a very complete report on his study of the photographic process, which embodies the views of many photographic chemists in this country and Europe on the possibility of improving the quality of sensitive plates employed in astronomical and physical observations. The opportune establishment in Rochester by the Eastman Company of a large and admirably equipped laboratory for photographic research, under the direction of Dr. C. E. Kenneth Mees, will probably render unnecessary any independent action on our part, since it is expected that just such problems as we have had in mind will be thoroughly worked out.

COMPUTING DIVISION.

The Computing Division has remained throughout the year under the direction of Mr. Seares.

Miss Burwell has devoted her time to miscellaneous investigations relating mainly to solar and stellar spectroscopy. She has measured and reduced 12 chromosphere spectrograms, 2 spectrograms of *Nova Geminorum* No. 2, and 242 stellar spectrograms for the determination of radial velocities. She has also measured a number of photographs made by the Hartmann method for testing the figure of the 100-inch mirror, and has done miscellaneous computing connected with the investigation of the sun's general magnetic field. Miss Burwell served as librarian from January 20 to May 1, 1913.

Miss Ensign has continued her work in connection with stellar spectroscopy. She has measured and reduced 1,050 spectrograms for radial velocities and has calculated and checked the reductions to the sun for a large number of plates. In addition she has measured several pairs of Hartmann test plates for the 100-inch mirror and has done miscellaneous computing and checking of calculations.

With the exception of a considerable amount of computing relating to the sun's general magnetic field, Miss High has devoted her time exclusively to the work in stellar photometry. She has measured and reduced 175 Polar Sequence plates, 28 plates of *RR Draconis*, and 105 plates of the Selected Areas. Miss High has also prepared identification charts for the 115 Selected Areas included in the program for the determination of photographic magnitudes, and has done miscellaneous work connected with the same investigation.

Miss Lasby has divided her time between stellar spectroscopic and laboratory investigations. Over 1,000 spectrograms have been

measured and reduced for radial velocity; she has computed the absolute velocities for about 60 stars of known parallax. The work relating to laboratory investigations included the measurement of photographs made by Mr. Gale at Chicago with the apparatus formerly used in the Pasadena laboratory to determine the shift of iron lines at low pressures. In connection with this, plates taken by Mr. Babcock covering the same region have been measured for the determination of the Zeeman effect. Several test plates for the 100-inch mirror were measured and also a few laboratory plates made for the determination of the Zeeman effect for chromium.

Mrs. Nichols has given much time to identifications and measures upon laboratory photographs of spectra, 124 plates having been examined and measured. In addition she has measured 23 stellar photometric plates and has assisted in the related reductions. She has also made extensive measures for screw-tests of seven comparators, and, in addition to general computing, assisted for about three months with the reductions of tertiary standards of wave-length.

Miss Myrtle L. Richmond was appointed to the division July 1, and thus far has been engaged with the measurement and reduction of photometric plates.

Miss Shumway has given her time wholly to recording and reductions connected with the investigations in stellar spectroscopy.

The measurement and reduction of the plates regularly made with the 5-foot spectroheliograph have remained in the hands of Miss Smith. The areas of the calcium flocculi on 258 spectroheliograms have been determined and 331 prominence plates have been measured. All reductions, including the fluctuation curves of the calcium flocculi, are complete to August 1, 1913. Miss Smith has made 502 prints of spectroheliograms, and about 400 other prints, the greater part of which are of the Selected Areas. She has also given some time to a detailed study of the structure of sun-spots, including the history, peculiarities, etc., of individual spots and groups.

Miss Mabel Van Deusen joined the division on August 1, and at present is engaged with star-counts upon photographs of clusters.

As during the preceding year, Miss Ware has been occupied mainly with work connected with the solar investigations of Mr. St. John. Many measures have been made on solar spectrograms for the determination of radial motion in sun-spots, and a large number of laboratory photographs have been measured and reduced for the purpose of determining tertiary standards of wave-length and testing the precision of wave-lengths measured with plane gratings. Miss Ware is at present engaged upon an extended series of measures for the comparison of arc and solar spectra.

Miss Haines continued as librarian until January 20. Since that date she has been on leave. Miss Burwell served until May 1, and

since then Miss Coral Wolfe has been in charge. The accessions of bound volumes during the year number 580, of which 285 were acquired by purchase, 266 by binding, and 29 by gift. The total number of bound volumes now in the library is 3,130.

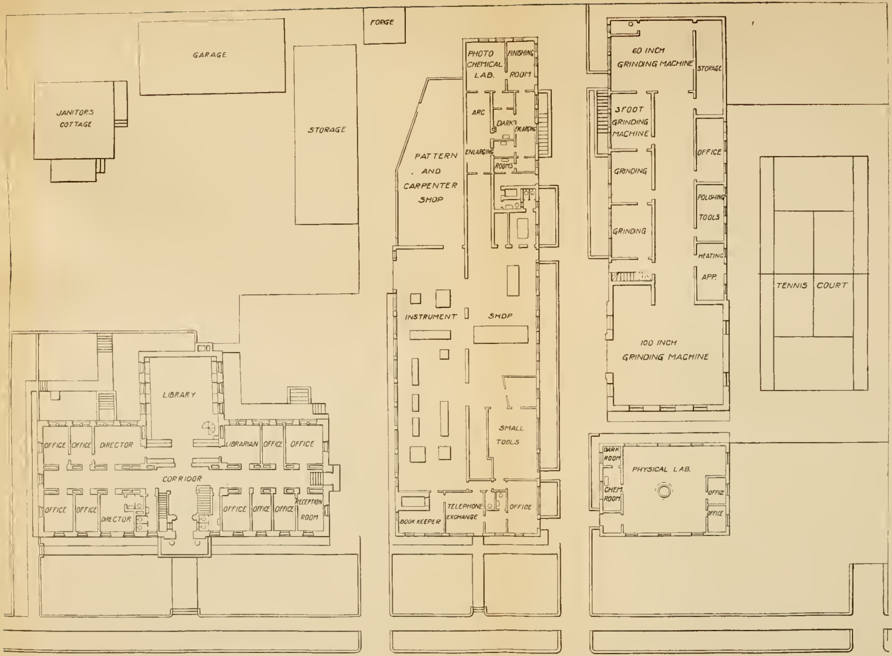
CONSTRUCTION DIVISION.

The fact that the 100-inch disk would prove suitable for use in the telescope, which was determined soon after the completion of the last annual report, has led to a great increase of activity in the Construction Division. As long as it remained uncertain whether a suitable glass disk for this telescope could be obtained it did not appear to be wise to proceed with the construction of the dome and mounting; but when the uncertainty was removed work was pushed forward in all departments. The Director and the Assistant Director have remained in charge of all construction, and have given much attention to the problems of design and execution of work. Mr. Ritchey has gone forward with the work on the 100-inch mirror and the 60-inch plane mirror for testing the former. Since the resignation of Mr. Drew on March 1, Mr. Pease has been in charge of all work of the drafting department, including the design of the 100-inch mounting, to which he has devoted most of his attention. Mr. Jones has remained in charge of building construction in Pasadena and on Mount Wilson, and Mr. Ayers has continued to superintend the work of the instrument shop. Dr. Anderson and Mr. Jacomini, aided by the instrument shop, have carried forward the work on the ruling-machine so rapidly that it is now nearly ready for a definitive test.

The problems connected with the construction and erection of the 100-inch telescope mounting and dome and the large auxiliary instruments required in its use have made two serious demands upon the observatory equipment. The first of these was for a more rapid means of transportation of large amounts of heavy material over the Mount Wilson road. The second was for larger machine tools with which to construct such portions of the telescope mounting, driving mechanism, and instrumental equipment as could be made to the best advantage in the Observatory shops. Much careful study was given to the question of meeting these two requirements.

MOUNTAIN TRANSPORTATION.

The experience of the Pasadena and Mount Wilson Toll Road Company during the winter of 1912–13 had shown that motor trucks could be operated successfully over the 9-mile road leading to the summit of the mountain, and in March of this year a 1-ton truck was purchased by the Observatory. This was followed in April by the purchase of a similar truck of 3 tons capacity. Both trucks are provided with excess water capacity to guard against overheating



Pasadena Grounds and Buildings of the Mount Wilson Solar Observatory.

the engines during the very severe service on the mountain grades. The exceptionally powerful engine and frame of the larger truck are supplemented with a special gear-train to permit the transportation of loads as great as 5 tons in case of necessity, at a low rate of speed. Both trucks have been in regular service since their purchase, and have made daily round trips from Pasadena to the mountain, with but very few exceptions. The rapid transportation of material in this way has made it possible to complete the large pier and the foundations for the 100-inch-telescope mounting and building within a single season. Moreover, it is greatly to the advantage of the members of the staff, who formerly walked or rode up the old trail, to be able to leave Pasadena any morning at 9^h30^m and reach the summit of Mount Wilson before noon.

The substitution of heavy motor trucks running daily for lighter mule teams going up on alternate days involves increased wear of the mountain road, which now demands more constant care. Additional daily labor will make it possible to continue the use of the road, almost without interruption, through the winter season, when it was formerly closed for several months. It will also reduce materially the heavy spring task of removing from the road the slides of earth brought down by winter rains.

CONSTRUCTION WORK IN PASADENA.

The trucks are housed in a garage built at the rear of the land, across the front of which stands the office-building. It is accordingly in a convenient position relative to the main shop-building and the storehouse at which most of the material for transportation is assembled. The garage contains space for four large trucks and is built of sheet iron, with a concrete floor. It has two repair pits and a tool and oil room, and is equipped with an underground gasoline storage system with a Bowser pump. The space between the garage and the rear of the office-building will be kept available for such portions of the telescope mounting as may require storage or erection in Pasadena previous to their transportation to Mount Wilson.

The requirement for larger shop-tools necessitated by the construction of many parts of the 100-inch telescope mounting and the auxiliary instruments to be used with it demanded an increase in the shop floor-space. Since the completion of the office building had made available a considerable amount of space in the Hooker building previously used for offices, the simple plan was adopted of transferring all of the optical work to this building and utilizing the room made in this way for the additional shop machinery. This plan has the obvious advantage of bringing all of the optical work into one building and of separating it completely from the machine-shop. A number of the partitions which separated the optical rooms have been removed, thus adding about 70 per cent to the original

main shop area. A separate room is devoted to some of the smaller machine-tools with which much of the work of the highest precision is done. The pattern-shop has been moved into an extension built at the rear of the carpenter-shop, so that the woodworking department is now essentially separated from the machine-shop and the fire risk is materially reduced. A well-equipped storage room for shop supplies has been made from a portion of the old optical testing-hall, and the small photographic dark-room has been remodeled into a lavatory and locker-room for the employees of the shop.

The following is a list of the principal machine-tools added to the shop equipment during the year:

No. 3 Cincinnati universal high-power milling-machine, with independent motor drive and heavy vertical milling attachment, universal milling attachment, circular milling attachment with power feed and 7.5-inch high-speed inserted-tooth milling cutter, in addition to regular equipment.
No. 31 Lucas horizontal boring, drilling, and milling machine, equipped with independent motor drive, star feed facing head, plain circular swiveling table, rectangular swiveling table with lock bolt, auxiliary table, and 10-inch high-speed inserted-tooth face mill.
G. A. Gray extra heavy pattern 36-inch by 48-inch by 12-foot planer, with one head on cross rail and one head on each housing, driven by direct connected slow speed 7.5 H. P. Westinghouse motor.
Mueller 3-foot standard radial drill with column extended one foot, equipped with worm, swiveling, and round tables and independent motor drive.
No. 1/2 Van Norman duplex milling machine, with index centers, collets, and vise and independent motor drive.
Knecht friction sensitive drill press, motor driven.
Brown & Sharpe 30-inch by 36-inch surface plate.
Crane, which serves assembling room, two drill-presses, and for loading and unloading at shop entrance.
Surface-grinding attachment for 24-inch by 24-inch Gray planer.

A small shop has been equipped for Mr. Jacomini, chief instrument-maker, in the basement of the new office building, where the conditions are extremely favorable for work of the highest precision and delicacy, on account of the massive walls and the constancy of temperature. The new equipment installed in this shop is enumerated below:

One 14-inch Pratt & Whitney lathe, 10-foot bed, motor drive.
One 14-inch Barnes lathe, 8-foot bed, for grinding and lower grade work, motor drive.
One Brown & Sharpe No. 2 A milling-machine, constant-speed motor drive.
One Atlas sensitive drill, motor drive.
One Hisey-Wolf pedestal grinder, motor drive.

In the Hooker building the wooden floors of the small offices have been removed completely and replaced by concrete, and a number of the offices have been joined into single rooms suitable for optical work. From these rooms several entrances lead into the main testing-hall. A portion of the northern end of the testing-hall has been transformed into a room for the grinding and polishing of the 60-inch plane mirror which is to be used in testing the figure of the 100-inch concave mirror. Doors open from this room into the testing-hall and in this way tests may be made upon both of the mirrors by rotating them to a vertical position without the necessity of moving them from their places. Smaller grinding and polishing

machines occupy the remainder of the space on the west side of the building. With the completion of the transfer of the photographic negatives from the plate vault in the Hooker building to the new office building, this room will be left available for the storage of optical disks, grinding and polishing tools, and general supplies of special value.

The strong need for well-equipped dark-rooms and enlarging rooms in which to carry on the increasing amount of photographic work required by the Observatory has led us to remodel for this purpose the rooms in the rear of the main shop-building, used as computing offices previous to the completion of the new office-building. Provision has been made for an office, two developing-rooms, an enlarging-room equipped with a Cooper-Hewitt arc lamp and projection apparatus for negatives up to 20 by 24 inches, a room in which is installed an instrument for enlarging and widening spectra, a room for chemical work and for washing negatives and photographic prints, a dark-room mainly used for sensitizing plates, and a room containing an electric plate-drier. A large amount of cupboard space is available for the storage of plates and chemicals.

In addition to these larger changes a number of minor alterations have been made. These have included remodeling two of the small offices at the front of the main shop-building in such a way as to provide office room for one of the laboratory observers; the construction of a concrete driveway between the shop and the Hooker building; and the erection of a small room above the photographic rooms for the making of blue-prints. The electric wiring system of the entire shop-building has also been modified and all exposed wires have been placed in conduits.

WORK OF THE INSTRUMENT SHOP.

The most important work of the year has been the construction of the large ruling-machine, under the supervision of Dr. Anderson, of the Johns Hopkins University. As explained in the last report, the machine was designed by Dr. Anderson, assisted by Mr. Pease, and embodies the general principles of Rowland's successful ruling-machines. Great care was taken in the selection of suitable metal for the castings, which were obtained from Brown & Sharpe, and for the screw and other parts of the machine. The extremely delicate and difficult operation of cutting the screw was carried out by Mr. Jacomini with great success, on the new Pratt & Whitney lathe, after the ways had been scraped, with the high degree of accuracy necessary for work of this nature. The method employed by Mr. Jacomini in cutting the screw greatly reduced the magnitude of the periodic errors below that usually encountered, so that the work of grinding was much facilitated. In grinding the screw Dr. Anderson employed Rowland's well-known method, but introduced impor-

tant refinements in the design and construction of the long nut, which was counter-weighted in order to relieve the pressure due to its considerable weight. The tests made from time to time during the process of grinding were extremely satisfactory, and a steady decrease in the errors was observed. The radius of the axis of the screw is over 200 miles, corresponding to a bend in the screw of less than 0.000001 inch. The bearings are now parallel to the axis within 0.00002 of an inch, but this quantity will be reduced later to one-quarter of its present amount. A preliminary interferometer test, made after the completion of the grinding and polishing, showed no periodic errors greater than 0.000001 inch, and no appreciable error of run has yet been detected. The maximum error in the teeth of the worm gear does not exceed 0.001 inch, which is too small to produce appreciable "ghosts." The definitive adjustments and tests of the machine will involve many months of cross-ruling. At present Dr. Anderson and Mr. Jacomini are devoting their attention to a study of various materials for end-thrust bearings, which are being tested experimentally under conditions exactly similar to those encountered in ruling. Hardened steel, agate, and ruby surfaces are being employed with the most promising results.

Meanwhile the less exacting work on the ruling machine has proceeded satisfactorily in the larger instrument-shop. The pattern work was begun in September, but for some months after the castings were received the machine work could not be pushed rapidly on account of the necessity of seasoning them by alternate exposure to heat and cold. Moreover, the large planer, not then installed, was needed for planing and grinding the bearings of the bed and cross-carriage. Recently the work has gone forward very rapidly, and the machine is now being assembled.

In addition to the construction of the ruling-machine the instrument shop has done the following work during the year:

15-foot concave-grating spectrograph, mercury contacts for tuning-fork, prism mounting, and generator mounting for physical laboratory.
30-foot and 60-foot lens mounting, liquid prism, additions to 75-foot spectrograph, and other minor work and repairs for the 150-foot tower telescope.
Completion of concave-grating spectrograph, small focal-plane spectrograph, and other additions and repairs to the 60-inch reflector and its accessory instruments.
Table-support, glass-testing mechanism, roller-bearing support, knife-edge, and other additions to the 100-inch grinding-machine equipment.
Focal-plane spectrograph, structural iron work on south pier, and other work in connection with the 100-inch reflector.
Continuation of work on 10-inch photographic telescope.
Miscellaneous accessories and repairs, work for mountain power plant, etc.

In addition to the above, the employees of the instrument-shop have devoted much time to the alteration and additions to the shop, including the cleaning and installation of new machinery, the moving of some of the older machines, and the construction and erection of cranes, tools, and attachments in preparation for the work on the

PLATE

LIBRARY IN THE OFFICE BUILDING, SOLAR OBSERVATORY

100-inch reflector mounting. As mentioned above, the focal-plane spectrograph for this instrument is now well under way, and patterns are now being made for the driving-clock castings.

PASADENA OFFICE-BUILDING.

The Observatory has enjoyed few advantages greater than those which have resulted from the occupation of the new office-building in Pasadena, which has been in use since January. The very small and crowded offices formerly available in the shop-buildings were often intensely hot during the summer months, to the serious detriment of the comfort and the efficiency of the staff. In the new building, on account of its massive construction, the temperature conditions are greatly superior, though the past summer has been exceptionally hot.

One of the most useful and attractive features of the new office-building is the library, where for the first time the books of the Observatory have been made readily accessible. An excellent copy in oils of Collier's well-known portrait of Sir William Huggins, made when he was President of the Royal Society, was offered by a friend of the Observatory for the decoration of this room. The library has grown steadily and now includes many sets of journals and publications of observatories, laboratories, and learned societies. Removed as we are from the great libraries of the eastern cities, it is important to extend this collection in several directions, and to complete imperfect sets, which will be done as rapidly as possible.

THE ONE-HUNDRED-INCH TELESCOPE.

In the last annual report the peculiar changes of figure observed when testing the 100-inch mirror were described. When the glass was hung on edge for testing, the figure was found to alter when the disk was rotated in its own plane. The observed effect was attributed by Mr. Ritchey to different degrees of compression of the disk along different diameters, under the pressure of its own weight.

To test the compression hypothesis a weight of 5 tons was supported on the upper edge of the glass, at the position angle corresponding to the "weak" diameter. When the point of support was brought into the neutral plane of the glass, found by experiment to be $5\frac{3}{4}$ inches from the rear surface, the figure was seen to be precisely the same as that observed when no pressure was applied. On either side of this plane the pressure introduced a component at right angles to the face of the disk, and thus caused a distortion of the glass. The solution of the whole difficulty was thus immediately suggested. It was found that the edge-band support, though made with unusual care, had not been properly applied. As soon as this was discarded and the glass allowed to rest on a shore-block of wood, with the point of support lying in the neutral plane, the figure was not changed in the least by rotation of the disk. Incidentally it

appears that the difficulty of securing suitable edge-supports for such mirrors has been exaggerated; a very simple device will serve perfectly if the pressure is applied in the proper plane.

As a further test of the suitability of the glass for use in the telescope, its figure was examined after the temperature of the room had been reduced to 45° F., and maintained at this point for several days. As no change in figure was observed, the temperature was raised to 95° F. and the tests repeated. These also showed the same figure as before. It thus appears to be safe to use the disk under the actual conditions of observation.

As a check on the visual knife-edge tests, they were repeated photographically and the figure was further controlled by means of the Hartmann test. The measures and reductions of the photographs were made by Mr. Adams, Miss Lasby, and Miss Burwell.

It is appropriate to express here our hearty acknowledgments of the unflagging interest and persistence of the French Plate Glass Company, which pursued costly experiments through several years in the hope of producing a flawless disk. We are also indebted to the Count de la Baume Pluvinel for his kindness in testing at St. Gobain a 100-inch disk of less thickness than the one selected.

Since the acceptance of the disk the work of figuring has gone on steadily, and has now advanced to a point where parabolizing may soon be undertaken. The figuring of the 60-inch plane mirror, for use in testing the 100-inch, has also been carried on simultaneously and it will be ready for use as soon as it is needed.

In the work of designing the mounting much practical advantage has been derived from the suggestions of Professor Peter Schwamb, formerly of the Massachusetts Institute of Technology, who has been engaged as our representative to superintend the work of construction at the Fore River Shipyards in Quincy, Massachusetts. Several valuable suggestions offered by Professor Schwamb have been incorporated in the design, and the work of construction is now under way.

The design for the steel building and dome for the 100-inch telescope was completed about June 1 by Messrs. D. H. Burnham & Co. of Chicago, and bids were secured from several contractors. Unfortunately, however, the figures were considerably in excess of the architects' estimates, on account of an increase in the market price of steel. After waiting several months, a new set of bids is being obtained, and the indications are that a very substantial reduction in cost will thus be effected. As our building program did not include the erection of the dome this year, there will be no delay on account of this experience. It is expected that the steel will be shipped to Pasadena early in 1914, and the work of hauling it to Mount Wilson can be undertaken in the spring in ample time for the opening of our construction season.

CONSTRUCTION WORK ON MOUNT WILSON.

The greater part of the construction work on Mount Wilson during the past year has centered about the 100-inch telescope pier and the foundations for the building. The site, which had been roughly graded the previous year, has been lowered an additional 3 feet and a concrete retaining-wall built around the south and west portions to prevent washing by the winter rains. The foundations for the building, consisting of two concentric rings of concrete piers, each 6 feet square at the base and 6 feet high, and amounting to 40 in number, were completed early in July and work was then commenced on the telescope pier. This is now nearly finished.

The pier proper measures 20 by 45 feet at the ground-level and is 32 feet 11 inches in height. On the south side is a long extension pier with a top sloping at an angle corresponding to the latitude of the observatory. This pier is designed to carry large fixed spectrographs and other apparatus intended for use with the telescope in the coudé form. In order, however, to avoid the necessity of constructing a pier with a very large upper surface the plan was adopted of mounting the instruments on brackets attached to its vertical face. The optical axis of the telescope passes about 2 feet outside of this face, a distance sufficient to allow for the use of the largest spectrographs. The height of the pier is such that a concave-grating spectrograph of 21 feet radius or a plane-grating spectrograph of 30 feet focal length may be employed if desired. The whole pier is inclosed by an outer concrete wall and roof to assist in maintaining a constant temperature.

The telescope pier itself is hollow in construction, with three heavily reinforced floors running across it at different elevations. The walls are also strongly reinforced and further strengthened by four buttresses on the outside, two each on the east and west sides. The first floor, at a distance of 16 feet from the ground, is designed to carry a large water-tank, which will form the reservoir for the water-circulation system enveloping the 100-inch mirror. At a height of 25 feet is the floor on which the driving-clock, worm-gear, and quick-motion right-ascension mechanism will stand. At the northern end on this floor is the room planned for the silvering of the large mirror. The electric elevator used for handling the mirror moves up and down through an opening 14 feet in diameter near the center of the pier.

The top of the pier consists of a circular concrete floor 11 inches thick and 53 feet 10 inches in diameter. On the east and west sides it is supported by massive reinforced concrete brackets extending outward from the pier. A metal wall about 8 feet high reaches from the edge of this floor to the level of the main steel floor of the building and the joint between the two may be made air-tight by means of a water seal, if found desirable.

With the completion of this pier the concrete construction work will be finished, with the exception of the floor at the ground-level. This will probably be delayed until after the erection of the building and dome and the heavier parts of the telescope mounting.

In addition to the work upon the 100-inch-telescope foundations, a considerable amount of general construction work has been completed. Two small wooden cottages have been erected, one of three rooms for Mr. Jones, the superintendent of construction, located near the 100-inch telescope site, and one of four rooms for the assistant engineer, near the power-house.

The need for additional space at the power-house has been felt strongly during the past year. Accordingly the building has recently been enlarged by an extension to the north to a distance of about 15 feet. This provides more space for the machine-shop, a small room for a blacksmith's forge, and a considerable amount of storage space for stock materials and tools. This construction, like that of the remainder of the building, is of reinforced concrete with a roof of steel.

The principal other piece of construction work during the summer has been a remodeling of the interior of the laboratory. With the increase in the number of observers, the need of more office room has been most evident. By means of a simple change in the location of the chemical room the entire southern end of the building has been made available for this purpose, and with the construction of a few partition walls, six additional small working-rooms have been added.

Other minor pieces of construction and repair work during the summer have included the laying of the remainder of the electric-power wires in underground conduits; the construction of a concrete muffling pit for the two gas engines of the power-house; the repairing of the laboratory roof; the construction of several short sections of new road on the mountain, and a considerable amount of brush-cutting with a view to the reduction of fire risks.

The Observatory has also built and installed for the Smithsonian Institution the mounting for a concave mirror of 75 feet focal length and for an auxiliary mirror to be used on the tower on Mount Wilson. The instrument will be employed for observations of the radiation at different portions of the sun's disk.

NUTRITION LABORATORY.*

FRANCIS G. BENEDICT, DIRECTOR.

While the internal affairs of the Laboratory have proceeded with reasonable rapidity and satisfaction, its environment has undergone radical changes. When the Laboratory was built, literally in the center of a vacant area, the probabilities of neighboring institutions were only dimly indicated on the engineer's blue prints. The fall of 1913 saw the completion and occupation of the large Peter Bent Brigham Hospital, the Collis P. Huntington Memorial Hospital, and the completion of the Infants' Hospital and the Children's Hospital. Active cooperation between the Laboratory and these institutions is finally assured.

The flexibility of construction of the Nutrition Laboratory sought for in the original design was well shown recently by the complete reconstruction of one room in the Laboratory, converting it from a chemical laboratory to a laboratory for physiological psychology. A balcony for records and for desk-room has been built and the main floor arranged for psychological tests. Photographic registration may be secured without difficulty, as the walls and ceiling of the room have been painted black and special shutters provided at the window. One corner has also been arranged as a dark room. The simple brick-wall construction of the building, without furring or plaster, and the absence of concealed pipes, made the complete reconstruction of this room a matter of relatively slight expense.

ADDITIONS TO EQUIPMENT.

CALORIMETER FOR MUSCULAR WORK.

The successful prosecution of a research on muscular work, in conjunction with Dr. E. T. Cathcart, of Glasgow, Research Associate of the Institution for 1911–12, emphasized the need for the immediate construction of a large respiration calorimeter to be devoted to experiments on muscular work; this had long been projected and in part built, but during the past year the construction was hastened and, at the moment of writing, the apparatus is practically ready for testing. In its construction we benefited very much by the experience of Professor Graham Lusk, of the Cornell University Medical School, who has built a respiration calorimeter after the design of the bed calorimeter in this laboratory, but with improved insulating material.

*Situated at Boston, Massachusetts. Grant No. 865. $46,549 for investigations and maintenance during 1913. (For previous reports on work in nutrition see Year Books Nos. 2–11.)

The new calorimeter is the largest ever built for man and is so constructed as to permit the measurement of the excessive amounts of heat given off by a man doing severe muscular work. The chamber is large enough for a man to stand upright in it and, indeed, to walk upon an inclined treadmill. The treadmill designed by Mr. Metcalf for use in this apparatus secures minimum friction and regularity of motion. For experimental work it is placed inside the respiration chamber and actuated by an electric motor. It is thus possible to measure the total carbon-dioxide output, oxygen consumption, caloric output, water vaporization, and the distance walked by a man on the treadmill, as well as the height to which the body is raised by the inclination of the treadmill. An extension in the top of the chamber permits the introduction of an endless ladder running over a large pulley, so that the subject can climb a ladder continuously, thus raising his body almost perpendicularly and doing a very large amount of work. By reversing the direction of the ladder and the treadmill the interesting problem of negative work can be especially well studied.

ELECTRICAL RECORDER FOR HEAT MEASUREMENTS.

The calorimeters in the Nutrition Laboratory are at present of the so-called continuous-flow type, *i. e.*, a current of cold water passing through an absorption circuit permits the carrying away of the heat as fast as it is developed. To determine the amount of heat given off by the subject, it is necessary to take the temperature of the water as it enters and leaves the chamber. In 24-hour experiments and in severe-work experiments this requires considerable labor on the part of the assistants, with possibility of error. An electrical recording device, which will graphically record the temperature differences of the water-current, has long been sought, and it was a cause of much disappointment that the recording device described in Publication No. 123 did not function perfectly for a reasonable length of time; but it is a pleasure to record the success of our physicist, Mr. E. H. Lange, in reconstructing this defective apparatus and making it practicable for experimental work.

RESPIRATION APPARATUS.

The form of respiration apparatus developed in this Laboratory, which is applicable alike for experiments with men, infants, and animals, has necessitated the construction of several other models, and there are now seven of the universal respiration apparatus in use in different parts of the Laboratory. Several modified forms of the spirometer used in connection with this apparatus have been built, one for permitting more accurate analysis of the curves corresponding to the volume of each individual respiration, and another

to provide for the enlarged volume of respiration incidental to severe muscular work. A third spirometer was constructed and loaned temporarily to Geheimrat Professor Dr. L. von Krehl of the I Medical Klinik in Heidelberg; this was copied by Professor Krehl and a similar one was constructed by Professor Otto Cohnheim, of Hamburg.

MODIFIED RESPIRATION APPARATUS FOR INFANTS AND DOGS.

While for several years a respiration chamber for use with infants and dogs has been employed in this Laboratory, in which the determination of the carbon-dioxide excretion has been satisfactorily made, it was deemed desirable so to modify the apparatus as to permit correct determination of oxygen consumption. During the past year this new form of apparatus was finally developed and at present gives admirable results for both the carbon-dioxide and the oxygen determinations, thus permitting many experiments upon the character of katabolism that were impossible with the older form of apparatus. Already several researches with dogs have been carried out with one of these chambers, and during the year almost daily experiments on infants have been made with a second apparatus. By means of the combustion of alcohol inside the chamber, the accuracy of the apparatus for making respiratory studies has been amply proved. The registration of minor muscular movements has been further developed, also a method for testing the sensitivity of the apparatus and securing a graphic record.

In order to compare the relative muscular activity of infants when inside the respiration chamber and when in the ward cribs in the hospital during the night, a cradle was constructed, one end of which was suspended by a helical spring, and kymograph records were secured during the night. These records have been of value in interpreting the muscular activity of infants supposedly quietly resting in sleep.

MISCELLANEOUS EQUIPMENT.

For a number of years the use of photographic registration apparatus in connection with the respiration calorimeters has been carefully avoided, but the potentialities of this form of record have now been recognized and this device has been adapted to many parts of the apparatus used in connection with the respiration calorimeter; consequently the equipment has been increased by nearly every form of photographic registration thus far devised. An Einthoven string galvanometer, constructed by the Cambridge Scientific Instrument Company, with its accompanying optical and photographic registration devices, has been installed in the Laboratory for physiological psychology; a Thoma oscillograph, which permits of the photographic registration of four different minute electrical currents of physiological significance, has also been purchased.

The laboratory equipment for the intimate study of the various chemical and physical factors entering into muscular work has been supplemented by the purchase of the new form of electrical ergometer devised by Dr. A. Krogh, of Copenhagen.

For the researches into the mechanics of respiration, which have been carried out by Mr. Carpenter, a 100-liter spirometer of the Tissot type with a recording apparatus has been secured. Among other minor apparatus may be mentioned a Kronecker inductorium and a cinematograph apparatus for studying by films the movements of men during muscular activity of various kinds.

For our clerical division two more dictaphones have been obtained and a specially constructed adding machine which enables rapid calculations, correct addition, and direct tabulation of results.

Sets of scientific journals used by the masters of physiology in publishing the results of their important researches have been purchased from time to time for our library. With the increasing number of regular and volunteer workers in the laboratory, the demands upon the library are becoming more and more evident each year. It is therefore desirable to have an equipment of the standard scientific journals, which will necessitate considerable additions in the near future.

COOPERATING AND VISITING INVESTIGATORS.

In the fall of 1912 an unusually large number of physiologists and physicians from Europe came to America, and a number of these visited the Nutrition Laboratory, inspected its equipment very carefully, and offered many interesting and valuable suggestions. Professor Gabriel Bertrand was commissioned by the Société Scientifique d'Hygiene Alimentaire of Paris to investigate the respiration calorimeters with a view to constructing such an apparatus in the new laboratory of the society in Paris. Special mention should be made of the visits of Professors Franz Tangl of Budapest, Karl von Noorden of Frankfort, and Max Rubner and W. His of Berlin.

Dr. E. P. Joslin has continued his cooperation in the study of diabetes mellitus. Dr. Fritz B. Talbot has been actively prosecuting a series of researches on the metabolism of infants in the children's ward of the Massachusetts General Hospital. Dr. Joseph H. Pratt completed the series of observations on meat feeding of dogs with atrophied pancreas, using the new respiration apparatus whereby oxygen determinations were secured.

Professor Raymond Dodge, of the department of psychology of Wesleyan University, spent the week-ends at the laboratory for the first half of the academic year of 1912–13, installing the apparatus in the psychological laboratory and making preparations for

a projected investigation on the psychological effect of food. He thus saved much valuable time and was enabled to begin active experimenting in the fall of 1913.

Dr. Paul Roth, of Battle Creek, Michigan, has constructed a respiration apparatus of the type developed in the Nutrition Laboratory and has been actively prosecuting researches on the metabolism of normal women subsisting on a vegetarian diet. During a visit to Battle Creek in January 1913, the Director personally supervised a number of experiments and assured himself of the correctness of Dr. Roth's admirable technique. The investigation is still in progress. Dr. Roth also spent some time at the laboratory acquiring the technique for operating the portable form of the Haldane gas-analysis apparatus and the making of alveolar-air determinations by the Haldane-Priestley method.

Professor H. M. Smith, of the chemical department of Syracuse University, kindly cooperated with us in an extensive series of experiments with young men on the effect of an acidosis, normally induced, carried out in the Nutrition Laboratory during the Christmas week of 1912. Subsequently Professor Smith became permanently attached to the laboratory staff.

Dr. J. H. Means, of the Massachusetts General Hospital, spent two months at the laboratory. During his stay he acquired the technique for operating the portable form of the Haldane gas-analysis apparatus and for making alveolar-air determinations by the Haldane-Priestley method. He also devoted considerable time to studying the construction and maintenance of the Benedict respiration apparatus and participated in the carrying out of experiments with it.

STAFF NOTES.

After a year of helpful assistance, particularly in the analysis of the mineral constituents of the urine and feces of the subject of the prolonged fast, Mr. Joseph Bock resigned to accept a position in the department of chemistry in the Cornell University Medical School.

Professor Raymond Dodge, of Wesleyan University, has been added to the staff as experimental psychologist and placed in charge of the laboratory for physiological psychology. Mr. E. H. Lange, formerly electrician in the Western Electric Company, was added to the laboratory staff as physicist. During the winter of 1912–13, Dr. S. Morgulis was actively engaged in experiments on animal metabolism.

In February 1913 the Director started on his third triennial tour of European laboratories, scientific institutions, and hospitals, visiting nearly all of the countries of Europe and paying special attention

to laboratory management, the purchase of new apparatus, discussions with foreign scientists on the many problems now under investigation at the laboratory, and particularly on the data obtained in the experiments during prolonged inanition and on the proposed investigation into the physiological and psychological effects of ethyl alcohol upon the human body.

In Paris numerous conferences with Professor Armand Gautier, the president of the Société Scientifique d'Hygiene Alimentaire, and various members of the special commission having in charge the construction of a new laboratory, led to the making of a formal series of recommendations. As a result, Mr. Lucien Bull, of the Marey Institute, was commissioned to visit the Nutrition Laboratory for a period of several months in order to study the type of respiration calorimeter here installed. A duplicate of one of the calorimeters is to be constructed in the new laboratory now being erected in Paris.

The investigation into infant metabolism, in conjunction with Dr. Talbot, necessitated a visit to the clinic and metabolism laboratory of Dr. Arthur Schlossmann, of Düsseldorf. The active investigators in Heidelberg were met in numerous conferences and assistance was rendered in planning for the construction, in the laboratory of the Medical Klinik, of a respiration apparatus of the type developed in the Nutrition Laboratory. To establish intimate relations with many Italian physiologists and pathologists several weeks were spent in Florence, Rome, and Naples. One of the most active laboratories in Europe in metabolism investigations is that of Professor Franz Tangl, in Budapest, and many discussions of experimental data and suggestions as to apparatus resulted from the visit.

In many ways Berlin, with its numerous physiological laboratories, particularly those of Professor Max Rubner and Professor N. Zuntz, is the center of German physiological research. The new medical clinics, particularly that of Professor His, and the recent development of electrical apparatus for studying the heart, offered excellent facilities for securing the newest physiological apparatus for the laboratory.

The opportunity of meeting Professor M. Schaternikoff was well worth the long trip to Moscow. Since the inception of the Nutrition Laboratory, it has been the policy of its Director to keep in intimate touch with Russian physiologists, and the visits to Moscow and St. Petersburg are always profitable. Unfortunately as yet there is no adequate system of abstracts in English, French, or German to cover the Russian periodicals.

As a result of the stay in Helsingfors, Finland, Dr. Carl Tigerstedt has been appointed as Research Associate of the Institution attached to the Nutrition Laboratory for the year 1913–14. American physi-

ologists owe a great debt to the senior Tigerstedt for his accurate translations of the reports of much American work that otherwise is disregarded by foreign writers. Dr. Klas Sondén, whose ingenious gas-analysis apparatus made possible the extensive study of the composition of the atmosphere recently completed in the Nutrition Laboratory, and Professor Johansson, whose studies in muscular work, fasting, and the ingestion of carbohydrates have been continually referred to in our work, assured a profitable visit to Stockholm.

At Copenhagen the laboratories of Krogh and Hasselbalch were visited. The large chamber for reduced pressures in the Finsen laboratory should lead to an illuminating series of researches. For the first time the laboratories of Professors Hamburger in Groningen and Professor Pekelharing in Utrecht were visited. American ideas of "luxury" were far exceeded in the equipment of the new buildings of Groningen. The Groningen Institute was well selected as the meeting-place for the Ninth International Congress of Physiologists. The researches on creatinine from the modest laboratory of Utrecht are of special value in interpreting the results of the long fasting experiment carried out last year at the Nutrition Laboratory.

The possibilities of the Thoma oscillograph have been admirably shown by Professor A. D. Waller, of London University, the pioneer in the study of the electrical action of the heart. Time was taken to secure sufficient evidence as to the practicability of the Thoma instrument to warrant its purchase for the laboratory. It is quite beyond the confines of this report to give an adequate statement of the innumerable benefits received during this trip or of the friendly interest shown in the Nutrition Laboratory.

Through the kindness of Professor Agazzotti, director of the laboratory in Turin, Mr. H. L. Higgins, of our staff, spent several weeks at Col d'Olen on Monte Rosa, working under the direction of Professor Galeotti, of Naples. On this tour Mr. Higgins likewise visited the laboratories of Oxford and Copenhagen and enjoyed for a time the courtesy of Professor Zuntz's laboratory in Berlin.

INVESTIGATIONS IN PROGRESS.

METABOLISM IN DIABETES MELLITUS.

Having successfully demonstrated the increased metabolism in severe diabetes and the coincidence of this increased metabolism with acidosis, several problems in relation to diabetes and metabolism presented themselves. Relatively few experiments were possible, owing to the difficulty of securing patients in the particular stages of the disease required for studying the several points, but a respiration apparatus was installed at the N. E. Deaconess Hospital and respiration experiments were there carried out on diabetics.

COMPARISON OF METHODS FOR DETERMINING THE RESPIRATORY EXCHANGE.

This research has been continued by Mr. T. M. Carpenter during the past year. The accuracy of the determination of the carbon-dioxide elimination in experiments on respiratory exchange by the Tissot and Zuntz-Geppert methods has been checked by introducing known amounts of carbon dioxide into the air-current of an artificial respiration apparatus. The necessity of using the delicate automatic counterpoise of the Tissot spirometer has been studied.

The practicability of the Mueller water-valves for separating inspired and expired air has been tested by running comparative experiments on the respiratory exchange, using other tested valves in the same series.

A method for determining the back-leak through respiration valves has been devised and employed in testing the various types of valves. The effect on the respiratory exchange of varying the speed of the circulating air-current in the Benedict respiration apparatus has been determined in comparative series of respiration experiments. Several series of control tests on the water absorbers, the ventilation measurer, and the 1-liter Bohr meter have also been carried out in connection with the use of the Benedict respiration apparatus.

The possibility of substituting stick yellow phosphorus for potassium pyrogallate has been thoroughly tested with both forms of the Haldane gas-analysis apparatus.

METABOLISM OF INFANTS.

In studying the metabolism of pathological infants, the same difficulty has been found as was observed in the studies with diabetics, namely, the lack of adequate normal values for comparison. In order to accumulate data with regard to the metabolism of normal infants of different ages, weights, and sex, a respiration apparatus giving determinations of both the carbon dioxide and oxygen was set up at the Massachusetts General Hospital and Miss Alice Johnson, of the laboratory staff, was placed in charge. With the cooperation of Dr. Fritz B. Talbot, an extensive series of experiments was carried out on normal infants varying in age from a few days to several months. Carefully selected periods of complete muscular rest were secured with practically all of the subjects, thus furnishing an excellent base-line for the discussion of the normal metabolism of infants.

THE NORMAL METABOLISM OF MEN AND WOMEN.

In connection with the numerous researches in metabolism carried on in the Nutrition Laboratory, data with regard to the metabolism of normal men are rapidly accumulating, but the use of women subjects is precluded in most experiments and hence a special research

has been undertaken to secure data regarding the metabolism of normal women. Mr. L. E. Emmes, of the laboratory staff, has been in charge of this research and nearly every day a new subject has been studied for the respiratory exchange in the post-absorptive state, *i. e.*, at least twelve hours after the last meal. The amount of data thus far accumulated is already considerable, but it will be supplemented as opportunity offers. In connection with the data being secured by Dr. Roth, of Battle Creek, these results should considerably extend our knowledge of the normal metabolism of women.

METABOLISM DURING AN EXPERIMENTALLY INDUCED ACIDOSIS.

The intimate relationship between acidosis and the increased metabolism in diabetes mellitus has led to a further substantiation of several preliminary experiments made a few years ago, in which a normal individual showed, as a result of the ingestion of a carbohydrate-free diet, an acidosis which led to an increased metabolism. During the latter part of 1912 experiments covering several days were made with four different subjects. The diet was carefully regulated and practically carbohydrate-free. The metabolism and the intensity of the acidosis were accurately studied. This series of experiments illustrates admirably the possibilities of research work in a laboratory of this type, since a large corps of assistants was able to study simultaneously a number of subjects, the diet, routine, and the normal control being identical in all cases.

ALVEOLAR AIR.

By means of the respiration apparatus, with its attached spirometer, it is possible to obtain in each respiration experiment the carbon-dioxide output, the ventilation of the lungs, and the respiration-rate. When determinations of the alveolar air by the Haldane method are made immediately before or after the experiment—the subject being in the same position as during the experimental period—it has been possible to calculate the dead space in breathing by a method similar to that recently described by Douglas and Haldane. With the same individual in the same position the volume of the dead space has been found to be very constant. Knowing the dead space, and reversing the calculation, it is also possible to obtain the alveolar air in each respiration experiment, from which one can learn whether or not the results obtained in a respiration experiment may have been due to abnormal respiration rather than to metabolic changes.

With the Haldane method studies were made (1) of the changes in the aveolar air due to the ingestion of food and (2) of a subject in different positions. The carbon-dioxide tension was found to be

higher after food than before, and also higher in a relaxed position than in an erect position. The conclusion drawn was that the respiratory center was influenced by some factor in addition to the hydrogen-ion concentration of the arterial blood.

THE DETERMINATION OF ACETONE AND β-OXYBUTYRIC ACID IN URINE.

The importance of the accurate and rapid determination of acetone and β-oxybutyric acid in a study of acidosis, and particularly diabetes, led to an attempt to better the existing methods. By modifying the condensing and the oxidation, the time required for the distillation of the acetone was materially shortened and control tests indicated a considerable increase in accuracy. It was estimated that the acetone and β-oxybutyric acid can be determined by this modified method in about one-third of the time formerly required, the apparatus being relatively simple and easily developed.

MINERAL CONSTITUENTS OF THE URINE OF A FASTING MAN.

Based upon his experience in the laboratory of Dr. Francis H. McCrudden, of the Rockefeller Institute for Medical Research, Mr. Bock has made complete analyses of the mineral constituents of the urine of the fasting man. Similar determinations of the mineral constituents of feces passed after concluding the fasting experiment contribute to the research as a whole.

VAPORIZATION CALORIMETER.

The principle of the large respiration calorimeter in this laboratory, *i. e.*, that of absorbing the heat given off by the man by a current of cold water flowing through suitable absorption pipes, is admirably adapted for measuring large quantities of heat. Since it seemed probable that another principle, which would do away with temperature measurements and secure continuous records, would be much more advantageous for measuring the small amount of heat given off by infants or by small animals, a research has been begun on the development of a calorimeter based upon the measurement of the amount of ethyl alcohol vaporized at extremely low pressure. Excellent progress has been made, although the calorimeter has not yet been fully developed.

PSYCHOLOGICAL OBSERVATIONS IN CONNECTION WITH EXPERIMENTALLY INDUCED ACIDOSIS.

One of the first problems undertaken by Professor Dodge, in the division of physiological psychology, has been the study of the influence of an experimentally induced acidosis upon the reaction time and the simpler reflexes. This was carried out in connection with the acidosis experiments made in the laboratory at the end of 1912, when the technique, method of handling the subject, and the order of tests were carefully studied, resulting in improved plans for further work.

STUDIES IN CHRONIC STARVATION.

Using the modified form of respiration apparatus, whereby both carbon dioxide and oxygen were determined, Dr. S. Morgulis made a series of observations on a dog undergoing chronic starvation with a period of realimentation. The dog was for a certain period of time somewhat underfed, with a gradual loss in weight; subsequently feeding was resumed, with a return to normal weight or even above. Special care was taken throughout the whole experiment to have the dog in excellent condition and thereby eliminate the influence of any abnormal factor.

INFLUENCE OF TEMPERATURE ENVIRONMENT ON METABOLISM OF ANIMALS.

By means of the new recording device for registering the muscular movements of animals, a series of experiments was begun to study the influence of temperature environment upon the carbon-dioxide production and oxygen consumption of dogs and other animals. In earlier experiments the influence of temperature environment has always been complicated by the unknown factor of muscular activity incidental to movements about the cage, or shivering. By means of the graphic record it has been possible to make studies in which the temperature environment alone, entirely independent of muscular activity, was the active factor. While the experiments thus far represent only a preliminary period of observation, it is proposed to carry on extensive investigations with different kinds of animals, particularly long-haired and short-haired dogs, studying the influence of clipping the hair, etc.

PUBLICATIONS.

The following publications have been issued:

(1) Die magnetische Reaktion einer zwischen den Polen eines Magnets kreisenden Kupferscheibe. W. G. Cady and F. G. Benedict. Phys. Zeitschr., 13, p. 920. 1912.

This article discusses particularly the mathematical features of interesting observations made upon the bicycle ergometer used in this laboratory for studying the muscular work of man. It represents a special treatment of the second part of Publication No. 167 of the Carnegie Institution of Washington.

(2) The influence of the ingestion of food upon metabolism. F. G. Benedict. Trans. Fifteenth International Congress on Hygiene and Demography, Sept. 1912.

The well-known increase in metabolism following the ingestion of food has been explained by various writers in different ways. This address considered the subject purely from the standpoint of evidence secured in the Nutrition Laboratory. A repetition of Loewy's experiments on the ingestion of saline purgatives showed no increase in metabolism, and the fact that the feeding of meat to dogs with deficient pancreatic secretion produced

no increased metabolism, although resulting in voluminous stools, pointed towards a complete refutation of the mechanical theory of the increased heat production. On the other hand, the results of studies in which sugar and other selected foodstuffs were given and particularly of experiments with diabetics and with normal individuals in acidosis led to the belief that the increase in the metabolism is due to "specific katabolic stimuli," probably of an acid nature, absorbed from the food materials in their passage through the alimentary canal, which produced an increased total metabolism and increased pulse-rate.

(3) Der Einfluss der Nahrungsaufnahme auf den Stoffwechsel. F. G. Benedict. Deutsch. Archiv f. klin. Med., 110, p. 154. 1913.

A German presentation of the above paper.

(4) The effect of carbohydrate-free diet on the dissociation curve of blood. (Preliminary communication.) J. Barcroft, G. Graham, and H. L. Higgins. Proc. Physiol. Soc. Jan. 18, 1913; Journ. Physiol., 15, p. xlvii. 1913.

A few preliminary remarks on work begun in Cambridge, England, in January 1911, and continued since in Cambridge and at the Nutrition Laboratory in Boston. The aim of the research was to study the influence of the acid products resulting from a no-carbohydrate diet upon the respiratory center and the dissociation curve of the blood.

(5) On the formation of fat from carbohydrates. Sergius Morgulis and Joseph H. Pratt. Am. Journ. Physiol., 32, p. 200. 1913.

Using the respiration apparatus for the determination of the carbon-dioxide output and the oxygen consumption, and feeding dogs having deficient pancreatic secretion with an excessive amount of glucose, it was possible to secure a respiratory quotient somewhat above unity, indicating the formation of fat from carbohydrate in the dog.

(6) The metabolism after meat feeding of dogs in which pancreatic external secretion was absent. Francis G. Benedict and Joseph H. Pratt. Journ. Biol. Chem., 15, p. 1. 1913.

The well-known increase in the total metabolism of both animals and man resulting from the ingestion of various kinds of food has been the subject of much study, and while investigators are well in accord as to there being such an increase, they differ widely in their opinion as to the cause. In general it may be stated that the theory most actively championed by Zuntz and his co-workers assumes that the increase in metabolism is mainly due to the mechanical processes of digestion, including the work of peristalsis, segmentation, absorption, and glandular activity. Rubner, on the other hand, holds that this increase is due to the specific dynamic action of the foodstuffs, *i. e.*, a quota of heat production that appears as free heat and does not benefit the cells. It is thus seen that in one case the increase in metabolism is considered to be due chiefly to mechanical causes, while in the other it is mainly attributed to chemical processes. With several dogs in which the pancreatic external secretion was absent, deficient food absorption was noted accompanied by voluminous stools. The passage of this large amount of unabsorbed material through the alimentary canal led to the view that such dogs would be excellent subjects for studying the influence of the ingestion of food upon metabolism and to secure evidence with regard to the mechanical theory of the increased heat production following the ingestion

of food. Based primarily upon the carbon dioxide excreted as determined with the respiration apparatus, a study was made with three different dogs, after feeding varying amounts of meat, and the results were compared with those obtained upon a normal dog similarly fed. An abstract of the results is given in the following table:

Comparison of the 24-hour increments in the carbon-dioxide production after feeding meat to three dogs with deficient pancreatic secretion and to one normal dog.

[On the basis of 7 kgms. of body-weight.]

	"Zep." (Fasting value 122 grams.)	"Pat." (Fasting value 126 grams.)	"Flora." (Fasting value 103 grams.)	"Clara" (normal). (Fasting value 122 grams.)
	p. ct.	*p. ct.*	*p. ct.*	*p. ct.*
Increase following feeding of 500 grams of meat.	20	17	....	31
	16	25	....	26
	13	23	....	28
	16	....	....	....
	16	....	....	....
	20	....	....	....
Average..............................	17	22	....	28
Increase following feeding of 750 grams of meat.	39	25	43	62
	56	....	....	....
Average..............................	48	25	43	62
Increase following feeding of 1,000 grams of meat....................................	53	....	....	....

From these results it will be seen that there is no large energy transformation incidental to segmentation, peristalsis, glandular activity of the stomach, liver, and intestines, and the movement of the unabsorbed food through the intestinal tract. The attempt to explain the increased metabolism following the ingestion of food by the theory that the increase is the consequence of such movement is therefore not justifiable.

(7) Ueber den Stoff und Energieumsatz bei Diabetes. Francis G. Benedict and Elliott P. Joslin. Deutsch. Archiv f. klin. Med., 111, p. 333. 1913.

This paper, which was prepared for German readers, presents a summation of the extensive series of experiments carried out at the Nutrition Laboratory during four years and reported in Publications Nos. 136 and 176 of the Carnegie Institution of Washington, and abstracted in the annual reports of this laboratory for 1910 and 1912.

(8) Muscular work: A metabolic study with special reference to the efficiency of the human body as a machine. Francis G. Benedict and E. P. Cathcart. Publication No. 187, Carnegie Institution of Washington, 1913.

This investigation, which was carried out by means of a special form of respiration apparatus and the bicycle ergometer described in an earlier publication (Publication No. 166 of the Carnegie Institution of Washington), considers two essentially fundamental questions—first, the character of the material burned in the body before, during, and after muscular work, and second, the relationship between the amount of effective muscular work and the total heat output, this comparison indicating the

mechanical efficiency of the human body as a machine. The subjects were all young men in perfect health, four of whom were unaccustomed to bicycle riding and the fifth a specially well-trained professional bicyclist with whom the larger portion of the experiments were made. All the experiments were carried out in the post-absorptive state, *i. e.*, at least 12 hours after the last food had been taken. The investigation extended over a period of several months and involved several hundred experiments.

It was conclusively demonstrated that during severe muscular work there is a distinct alteration in the character of the materials burned in the body, as the evidence indicated a selective combustion of carbohydrate material, although the experiments do not point to an exclusive combustion of carbohydrate during muscular work.

The major portion of the experiments was devoted to a study of the relationship between the total heat output and the effective external muscular work, thereby giving information in regard to the mechanical efficiency of the man. The net efficiency (E) of the body would be represented by $E=\frac{W}{C}$, in which W is the external work expressed in calories and C the total caloric output of the body. With small amounts of work, W is small and the efficiency is low. If the heat output necessary for maintenance is deducted from C, the efficiency obviously becomes greater. The needs for maintenance increase directly, depending upon whether the subject is lying quietly in bed, sitting upright on the ergometer doing no work, or rotating the pedals with no resistance or with varying intensity of resistance. Each stage of activity represents a different base-line, and by superimposing more severe work upon the various base-lines the increments in the total heat production and in the work done could be determined and the ratio between them, *i. e.*, the mechanical efficiency, readily computed. An extensive discussion of these various base-lines and of what is meant by "gross" and "net" efficiency, together with the careful computation of the maximum efficiency, leads up to an interesting discussion as to the analysis of the chemical and thermal processes involved in severe muscular work.

Besides the two main themes, the report considers numerous other important questions relative to the muscular work of man, such as the effect of muscular work on the pulse-rate, the body temperature, the mechanics of respiration, and the drafts upon the body-material, the maximum working capacity of man, and particularly the after-effects of work. A certain amount of evidence was available for a comparison of results obtained with trained and untrained individuals.

Under certain conditions, particularly when the subject is riding with a moderately severe load and immediately begins riding with a very severe load, it is possible to superimpose a load upon the human body so that 40 per cent of the increment in the total heat output may be in the form of effective external muscular work transmitted to a machine, such as the bicycle ergometer. No indication was given of the possibility of "overloading" the human machine so far as mechanical efficiency was concerned. Obviously the power of human endurance is limited, but an interesting point is the fact that the professional bicyclist performed all of the experiments without food and that on at least one day he did an amount of work equal to a "century" run over ordinary roads. This experiment gave the data for computations in regard to the probable amount of available glycogen in the human body.

The report is accompanied by an extensive review of the earlier literature with an analysis of the results obtained by former investigators.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. Bauer, Director.

GENERAL SUMMARY.

The chief operations and results of the Department during the period November 1, 1912, to October 31, 1913, may be summarized as follows:

MAGNETIC SURVEY OF THE OCEANS.

The second cruise of the *Carnegie*, begun at New York on June 20, 1910, was very nearly concluded at the end of the present fiscal year. She has been in continuous commission for somewhat over three years, Mr. W. J. Peters having been in command throughout. During this period the *Carnegie* has been making a complete circumnavigation of the globe, the aggregate length of the cruise being over 92,000 miles.†

Accurate magnetic data have now been obtained by the Department in all the oceans near the tracks usually followed by vessels, between the parallels of 50° north and 50° south. The total length of the cruises along which these data have been secured, during the period 1905–1913, was 60,000 miles for the *Galilee* (1905–1908), and for the first and second cruises together of the *Carnegie* (1909–1913) 100,000 miles, or of the two vessels, 160,000 miles.

Owing to the promptness with which the results of chief interest to the mariner were made known, it has been possible for hydrographic establishments to revise or issue corrections to their magnetic charts before the completion of the present cruise. It is gratifying to report that smaller chart errors than was the case on the initial cruises of our vessels are now being found in parts of the oceans chiefly traversed.

The future work of the *Carnegie* will consist in obtaining magnetic data either in the areas not yet covered or where the past observations had to be meager because of cloudy or stormy conditions encountered. She will at the same time intersect her previous tracks as frequently as possible in order to obtain at these points the amount of annual change in the magnetic elements—data urgently needed in order that magnetic charts may be kept corrected up to date. An

*Address: The Ontario, Washington, District of Columbia. Grant No. 827. $110,263 for investigations and maintenance during 1913, and $100,000 for purchase of site and erection of Office and Laboratory Building. (For previous reports see Year Books Nos. 3–11.)

†The *Carnegie* returned to Brooklyn on December 19, 1913.

instance is cited under "Details of the Ocean Work" showing that, with the refined appliances and methods in use on the *Carnegie*, reliable data for correcting the charts can be obtained in a comparatively brief interval.

It is hoped, by the end of next year, to issue a complete report containing the results of all the scientific work accomplished on the oceans by the *Galilee* and *Carnegie*.

MAGNETIC SURVEY OF LAND AREAS.

During the present fiscal year there have been several noteworthy land expeditions, all of which were accomplished by the respective leaders with entire success. Thus Observer D. W. Berky, assisted by Observer H. E. Sawyer, completed a trip across the Sahara Desert, leaving Algiers at the end of October 1912 and arriving at Timbuktoo on May 12, 1913. This may have been the first American party to make this trip. Every possible courtesy and assistance was rendered by the French officials. Messrs. Berky and Sawyer next extended their magnetic survey into the countries of West and Central Africa bordering on the Atlantic Coast.

Dr. H. M. W. Edmonds, magnetician, assisted by Observer D. M. Wise, from May to October, explored the region of Canada to the west of James Bay and Hudson Bay, of special interest because of the fact that one of the foci or areas where the intensity of the Earth's magnetic field is a maximum is located here. The canoe route which had to be traversed approximated about 2,000 miles, of which over 500 miles was over an unsheltered, open coast.

Observer A. D. Power not only has completed a valuable series of magnetic stations in northern Venezuela, but had accomplished safely also, by the middle of August, the important trip along the Orinoco River and Rio Negro, from the mouth of the Orinoco to Manaos, on the Amazon. During the remainder of the fiscal year he was engaged in carrying out an expedition from Manaos to the boundary of British Guiana, via the Rio Negro and Rio Branco. He succeeded in penetrating into British Guiana and connecting with our 1908 series of stations as far as Georgetown.

Observer H. F. Johnston, after having been relieved of ocean duty at Bahia, Brazil, last May, undertook to push northward in South America a series of stations from Montevideo, Uruguay, along the Parana, the Paraguay, and Madeira Rivers to the Amazon at Manaos. By the end of October he had completed his expedition as far as Asuncion, Paraguay.

Thus, before long we shall have, in addition to the chain of magnetic stations already extending completely across South America,

from Para, at the mouth of the Amazon, to Callao, Peru, one through the central part of South America from north to south, and moreover, with the aid of the work accomplished by Observer H. R. Schmitt in Peru, Bolivia, and Chile, a chain along the whole Pacific Coast.

Further good progress has been made by Observer E. Kidson, in charge of the general magnetic survey of Australia and outlying islands, his work having been for the greater part of this year in Queensland, Victoria, New South Wales, and Federal Territory. As the result of his training of the chief magnetic observer of the Mawson Antarctic Expedition, Mr. E. N. Webb, there was sent to the Department for reduction, in the early part of this year, a highly valuable series of magnetic observations made in the vicinity of the South Magnetic Pole. Mr. Webb was appointed a temporary observer and assigned to Mr. Kidson in 1911 for the prime purpose of being fitted and trained for the proposed magnetic work in the Antarctic region. The Department had also supplied the magnetic outfits. Mr. Webb deserves high praise for the amount of work accomplished under trying and adverse conditions.

STATUS OF GENERAL MAGNETIC SURVEY.

Special effort will be made during the next year to cover the remaining unexplored regions, if only in a general way, not yet included in our survey. The aim is to make an attempt by 1915 to construct a new set of magnetic charts, embracing all of the magnetic elements (declination, dip, and intensity of field) and covering the regions of the Earth from 50° north to 50° south. It will then be possible to enter upon the solution of several of the important outstanding questions in terrestrial magnetism. It is proposed to select for this first or preliminary magnetic survey of the Earth the middle date, January 1, 1910, to which all of the observations secured by the Department, 1905–1915, and by cooperating institutions, are to be referred.

By the time the Department is prepared to issue its next set of magnetic charts (for 1915) it is hoped that the polar regions may also be successfully included. At present, the data for these regions are still too scanty. However, owing to the various projected polar expeditions, the next few years will witness valuable and extensive additions.

The Department is working in effective cooperation with the chief expeditions by supplying instruments, training observers, and furnishing data and directions for the work which is to be undertaken. It refuses its cooperation with expeditions if the organization and personnel are such as not to make it fairly certain that reliable data will be obtained. Data of indifferent value, in the present state of

the science, are not wanted, as their use may lead to more erroneous conclusions than if there were no data at hand.

While by far the major part of the present magnetic survey of the globe is being done by the Department, the cordial and effective cooperation received from the various magnetic organizations in civilized countries should not be left unmentioned. It is also of interest in this connection to record the following resolution, which was passed at the request of General Rykatchew, at the meeting of the International Association of Academies, held at St. Petersburg last May:

> The committee, in view of the work of making a magnetic survey of the globe, particularly on the oceans, undertaken by the Carnegie Institution of Washington, resolves that it is of the highest importance that similar work be completed, as soon as possible, in those countries where no surveys exist or where they have been made at epochs relatively distant from those of the Carnegie Institution of Washington.

WORK IN WASHINGTON.

The most noteworthy event to be chronicled under this head during the year is the purchase of a tract, comprising about 7 acres, admirably located in the vicinity of Rock Creek Park, about a mile to the north of the Bureau of Standards and the Geophysical Laboratory, and the erection thereon of a fireproof building 51 by 102 feet, consisting of basement, two stories, attic, and observation-roof. The erection of this building, designed by Mr. Waddy B. Wood, in accordance with the preliminary plans drawn up by Mr. Fleming of the Department, was begun in May last, and, according to the present rate of progress by the builders, the Davis Construction Company, of Washington, it is expected that the Department may occupy its new quarters early in 1914. Mr. Fleming has had general supervision of the construction of the building.

The basement will provide quarters for the instrument-shop and storage of instruments. The first floor will be devoted to a magnetic laboratory and experimental work in connection with the field-observational work. For certain experiments there will also be available two rooms in the basement, as also two constant-temperature rooms in the sub-basement. The office, computing rooms, library, and archives will occupy the second floor. The attic and roof are designed to meet the requirements of special observational and experimental work.

The grounds are ample and are sufficiently remote from disturbing influences, so that the testing and comparisons of magnetic instruments and work in atmospheric electricity may be successfully carried on. The Department will thus in future enjoy exceptional facilities for its work.

The work at present being conducted in the subjects of terrestrial magnetism and atmospheric electricity is mainly observational: Either the magnetic or electric elements are determined at suitably distributed points over the Earth with the view of obtaining, as accurately as possible, a knowledge of the Earth's general magnetic or electric condition (magnetic or electric surveys); or at a considerably smaller number of points are registered the variations to which the magnetic and electric elements are subject with time and with varying planetary and solar conditions (observatories). There are thus magnetic and electric surveys, and magnetic and electric observatories; but hitherto no laboratory has been established for the specific purpose of assisting in the physical interpretation of the particular phenomena in terrestrial and cosmical physics here concerned. The recent rapid progress in the science of astrophysics is doubtless attributable in no small measure to the combination of laboratory with observational facilities and the enlistment of the physicist and the mathematician in astrophysical problems. Just so should it be and must it be with the closely related subjects, terrestrial magnetism and terrestrial electricity, before similar progress may be recorded.

The questions which are now continually arising with the advance in the observational and investigational work of the Department are partly experimental and partly theoretical in their nature. While the special purpose of our laboratory must necessarily be to supply the facilities to assist in the solution of these questions, it will often arise that investigations in the general subject of magnetism and electricity and allied subjects can profitably be undertaken, provided the facilities be adequate. It is in fact often difficult to draw a sharp dividing line between special and general interests and it is a noteworthy fact that the most promising research work is being done in the borderland or "twilight zone" of the older-established sciences. Dr. W. F. G. Swann, formerly of the University of Sheffield, has been secured as chief physicist for the proposed experimental work.

In spite of the amount of attention which has had to be devoted to the planning and supervision of the Office and Laboratory Building, the final reduction of the field observations has been making such good progress that within a few months the manuscript for the second volume of Researches of the Department, containing the land magnetic observations for the two years 1911 and 1912, will be ready for the press. Good progress has also been made with the manuscript for the volume to contain the ocean observations. The tables of magnetic declination for the ocean work and chart corrections have been published promptly, for each cruise, in the journal Terrestrial Magnetism and Atmospheric Electricity.

The compilation of past data has been continued and the effort has been made to determine characteristic or suitable regions where

future special observational work should be undertaken for the solution of such questions as, for example, the effect of locally disturbed areas on the secular variation, or the change of the intensity of the Earth's magnetic field with altitude, etc. A critical sifting of the available observatory data has also been begun so as to secure reliable information regarding the secular and other magnetic variations in various parts of the Earth, for use in the construction of the magnetic charts referred to above. Discontinuities are at times found in the observatory series, the cause of which can not always be definitely ascertained from the published reports; thus correspondence with the respective directors is necessary. In fact, the present lack of uniformity in method of observation and the need of adequate publication are of serious concern. Unless an observatory has sufficient funds and the required personnel to make possible the prompt and full reduction and publication of its observations, it is very much to be questioned, in the light of all the experience, whether a gain to science will result by the continuation of its observational work.

The Director has continued, as far as his other duties permitted, the researches on the physical theory of the Earth's magnetism and electric phenomena, as also some investigations respecting the secular variation. He has likewise made a preliminary analysis of the Sun's general magnetic field as disclosed by the published observations at the Mount Wilson Solar Observatory. On May 22 he delivered the Halley Lecture on Terrestrial Magnetism at the University of Oxford, England; also, at Berlin, May 3, and at London, June 4, he gave addresses on the status of the work of the Department.

Dr. Swann during October devoted his attention chiefly to a study of the observations in atmospheric electricity made aboard the *Carnegie*, with the special view of ascertaining the directions in which the future work may be improved and amplified. This led to an examination of the theory of the instruments and methods used in atmospheric electric work, several highly important conclusions being reached, of theoretical as well as of experimental interest.

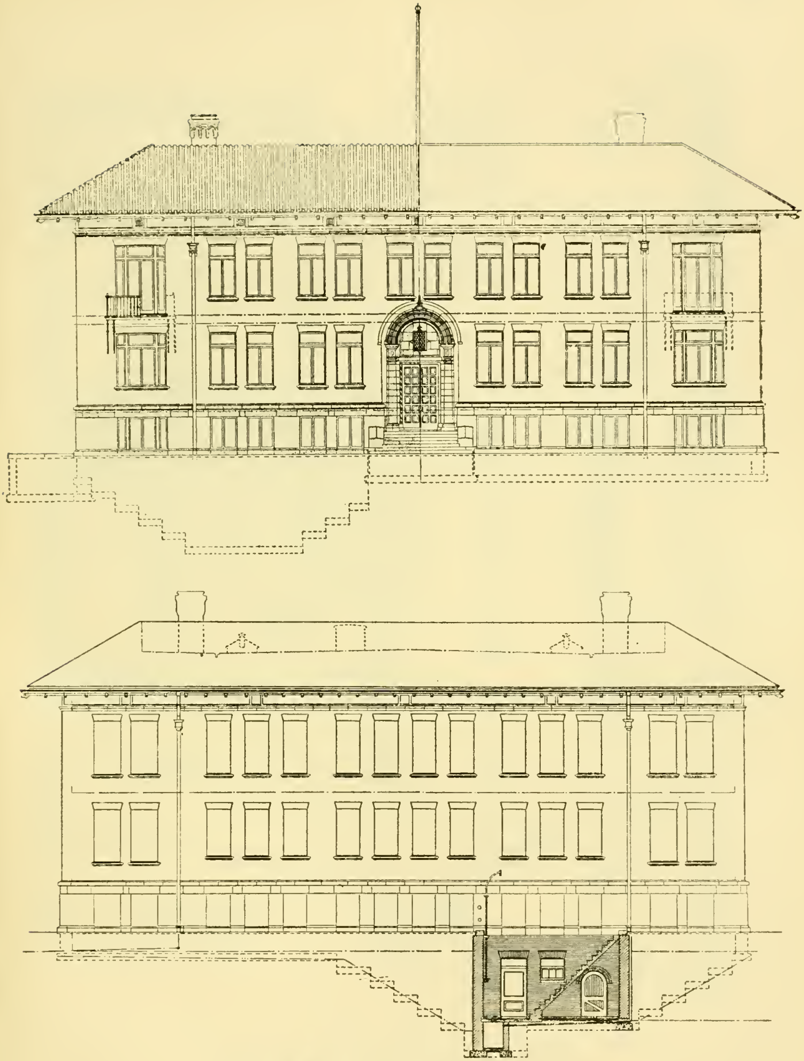
The magnetic instruments used on land and at sea have received further improvement during the year, such as experience gained in all parts of the Earth has suggested. Nearly all of the instruments used are now being constructed in the workshop of the Department.

The status of the observational work of the Department to date is shown on plate 13.

A list of the published papers by members of the Department will be found in the Bibliography.

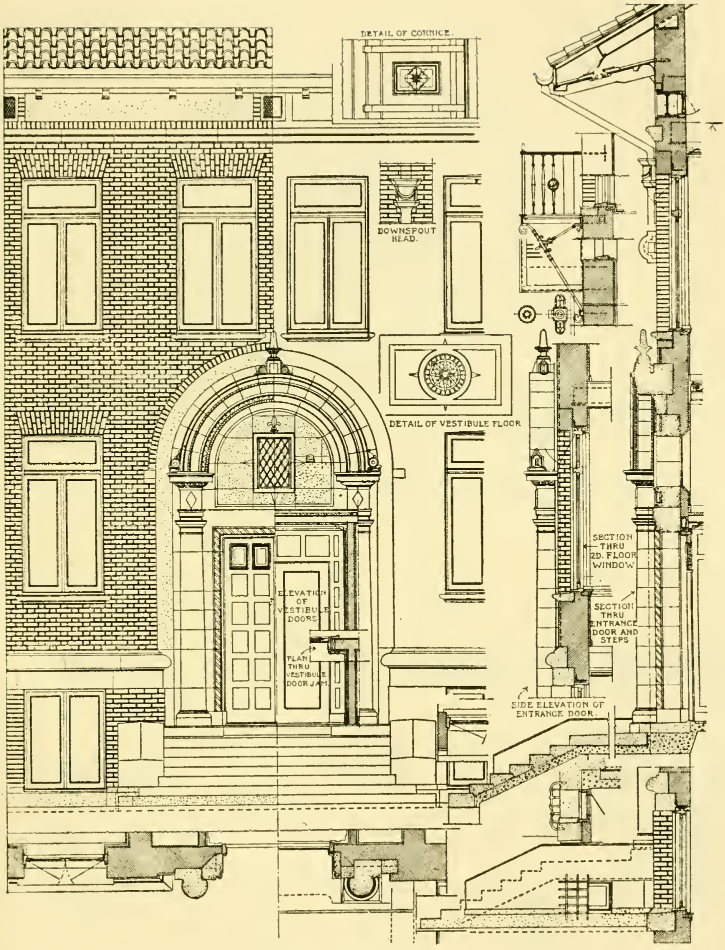
The quantity and quality of work accomplished during the year are evidence of the zeal and ability shown by the members of my staff.

PLATE 8



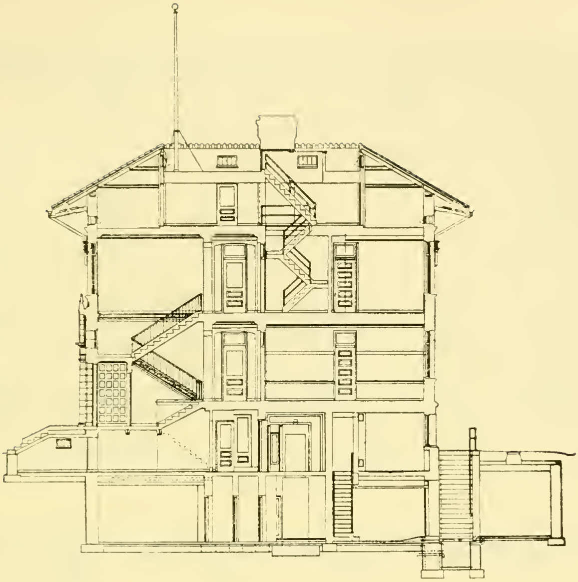
Upper figure: Front View; Building Faces Southwest.
Lower figure: Rear View; Shows Entrance to Sub-basement.

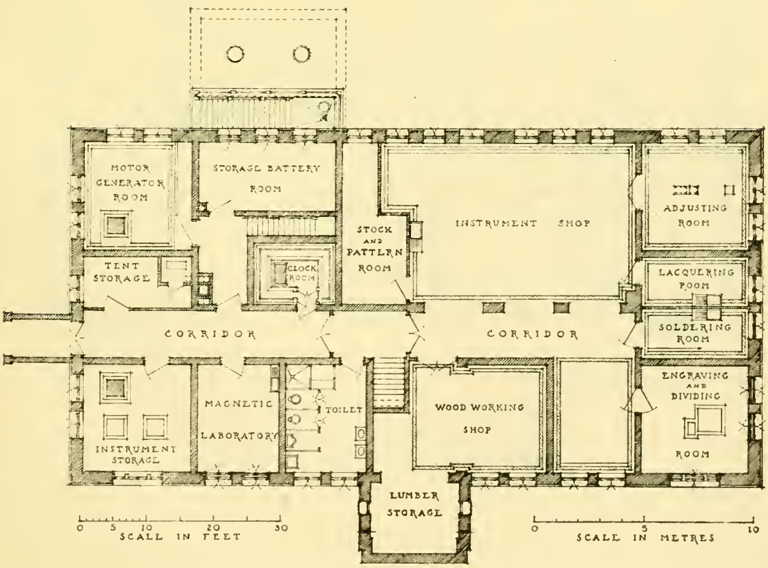
Department of Terrestrial Magnetism.



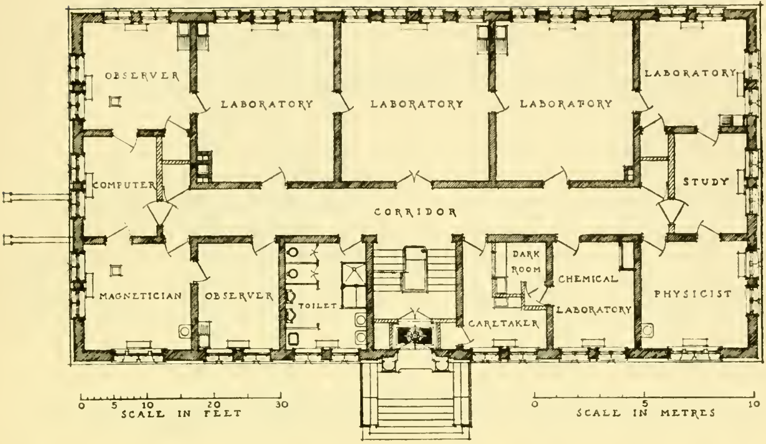
Details of Entrance.

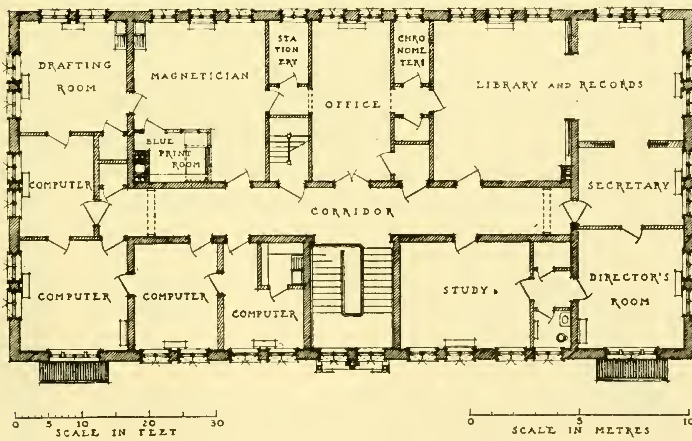
Department of Terrestrial Magnetism.



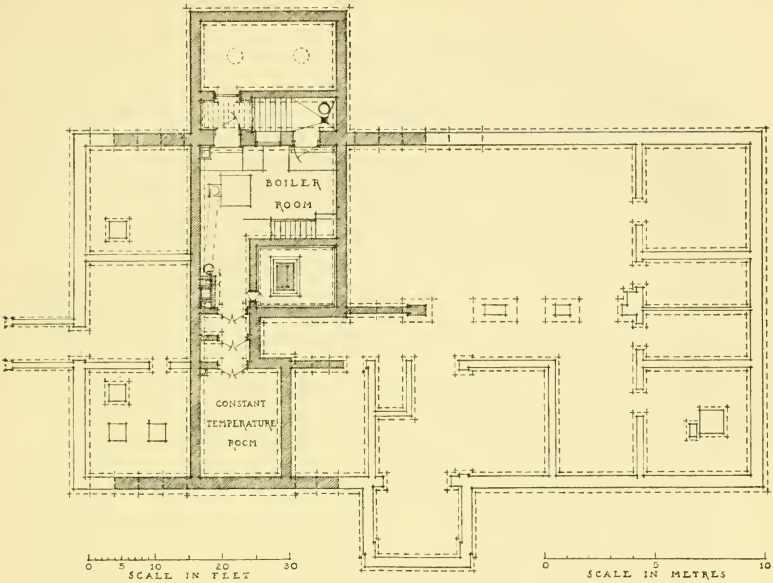


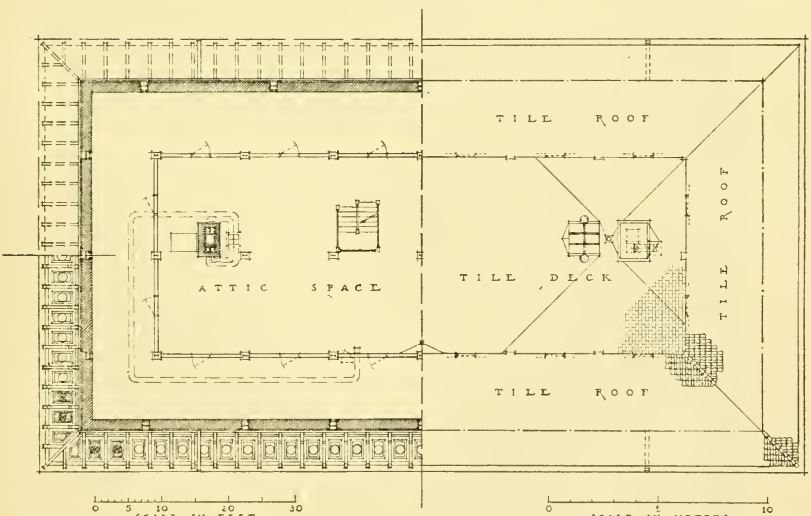
Upper figure: Transverse Sectional View.
Lower figure: Instrument Shop, Basement.
DEPARTMENT OF TERRESTRIAL MAGNETISM.





Upper figure: Magnetic Laboratory, First Floor.
Lower figure: Office and Archives, Second Floor.
Department of Terrestrial Magnetism.





Upper figure: Sub-basement and Constant-temperature Rooms.
Lower figure: Half Plan of Roof and Observation Deck.

DEPARTMENT OF TERRESTIAL MAGNETISM.

DETAILS OF OBSERVATIONAL WORK.

OCEAN WORK.

The ocean work of the Department has been continued by the *Carnegie* in the Pacific and Atlantic oceans. At the close of the last fiscal year she was en route from Tahiti to Coronel, where she arrived on November 25. Here the magnetic station established in 1907 by the *Explorer*, of the United States Coast and Geodetic Survey, was reoccupied. After the necessary land observations had been made for the determination of constants and intercomparisons of instruments, the *Carnegie* proceeded to Talcahuano on December 4, arriving there December 5. At this port, through the courtesy of the Chilean officials, the government dry-dock was used for dry-docking the vessel and carrying out the necessary repairs. While at Talcahuano opportunity was given Observers Hewlett and Johnston to visit Dr. Walter Knoche, in charge of the meteorological work for the Chilean Government at Santiago, and to discuss with him methods of work in atmospheric electricity at sea. Subsequently Dr. Knoche visited the *Carnegie* at Talcahuano and kindly made some further suggestions.

Leaving Talcahuano December 19, the *Carnegie* proceeded next to Port Stanley, Falkland Islands, arriving there January 27, 1913. A northwest course was followed to about 26° south latitude and 95° west longitude, thence southwest to about 40° south latitude and 107° west longitude, and thence around Cape Horn to Port Stanley. Winds of great strength prevailing for days at this port, considerable delay was experienced in the completion of the work, which included a reoccupation of the magnetic station given in the British Admiralty List. Upon one occasion while in the harbor the *Carnegie* dragged her anchor. Dr. H. M. W. Edmonds was relieved of ocean duty at Port Stanley in order to take charge of the land expedition to Hudson Bay, and Dr. C. C. Craft was assigned as surgeon and magnetic observer.

The *Carnegie* sailed from Port Stanley on February 22, 1913, bound for St. Helena, following a great circle route to 46.5° south latitude and 1° east longitude. Along this portion of the passage a number of large icebergs were seen. The track of the *Carnegie* in 1911, as well as that of the *Gauss* while on her Antarctic cruise, was crossed. The *Carnegie* was "swung" at sea on March 21, and it was once more found that the magnetic observations (dip and intensity) made on the various headings agreed with each other within the observational errors. Arriving at Jamestown, St. Helena, on April 3, the stop made this time was only long enough to provision the vessel, attend to the accumulated correspondence, and dispatch the observation records to Washington. In order to make the more southerly return passage, as planned from Bahia to St. Helena, before the Sun had reached the summer solstice, the usual shore-work was postponed

and Jamestown was left on April 9 and the course set direct for Bahia. En route observations of the magnetic declination were made during a complete swing of the vessel, confirming the absence of possible deviations greater than the error of observation.

Bahia was reached on April 24. Here extensive intercomparisons were made ashore of all instruments used aboard and, as the Brazilian station at Bahia was no longer suitable for secular variation purposes, a new magnetic station was established on Jaburn Island. Observer Schmitt joined the *Carnegie* at this port in place of Observer Johnston, who had been assigned to take charge of important land magnetic work in Paraguay, Uruguay, Argentina, and Brazil. Mr. Johnston reoccupied the magnetic station of the United States Coast and Geodetic Survey, established by the *Explorer* in 1907.

After completion of the land work, the *Carnegie* sailed from Bahia on May 19 for St. Helena, following a south and east course to about 36° south latitude and 6° west longitude, and sailing thence north to St. Helena, where she anchored in Jamestown harbor June 23. On this passage considerable cloudy and stormy weather was experienced. Complete intercomparisons of all instruments were now made ashore and one magnetic station of the *Gauss* expedition was reoccupied.

Leaving Jamestown on July 21, a north-northwest course was followed to about 30° north latitude and 35° west longitude, and then north-northeast and northeast courses to Falmouth, where the vessel arrived September 12. On August 16 and 18 magnetic observations were obtained on eight equidistant headings of the ship, the previous conclusions regarding absence of appreciable ship deviations being again confirmed.

During this passage from St. Helena to Falmouth, the *Carnegie* on August 10 crossed her track of 1909. A comparison of the value of the magnetic declination obtained at the point of intersection, once in 1909 and next in 1913, showed that the north end of the compass needle had shifted westward at an average annual rate of 5 minutes; this is in the right direction to account to some extent for chart errors. A reliable value of the secular change derived from sea observations for an interval of not quite four years can only be obtained by means of the refined methods and instruments in use on the *Carnegie*.

At Falmouth, besides the usual shore comparisons of instruments, the stations established by the *Carnegie* during her first call at this port in October 1909, at Trefusis Point and St. Anthony, were reoccupied for the purpose of determining the secular change in the magnetic elements since 1909. For the same purpose magnetic observations were made at the two nearest stations of the Rücker and Thorpe Magnetic Survey of Great Britain, namely, Truro and Porthallow, thus giving additional data for connecting this admirable land survey with the work of the *Carnegie*. The *Carnegie* was also

once more "swung" in Falmouth Bay and complete magnetic observations were made over the same place where similar work was done in 1909; the 1909 results were confirmed.

On October 15, the *Carnegie* left Falmouth on the last leg of the long cruise begun in June 1910. At the end of the fiscal year she was homeward bound and on December 19, 1913, she arrived at Brooklyn.

The length of the portion of the entire cruise accomplished during the fiscal year approximates about 30,000 miles. In addition to the shore work, already described above, the ocean work was as follows: The magnetic declination was determined at about 240 points and the magnetic dip and intensity at about 200. Atmospheric electricity observations were made as opportunity permitted, and additional equipment has been provided for this work. The meteorological observations, observations of refraction, and hypsometric observations have been continued as in previous years. Also, a number of special investigations were made covering various questions, the details and results of which must be reserved for the fuller publication.

The vessel continued throughout the year under the able command of Mr. W. J. Peters. Besides changes of observers already mentioned, Mr. M. Clausen succeeded as first watch officer Mr. Erns Laursen, who resigned when the vessel arrived at Coronel. Mr. Peters refers in appreciative terms to the effective and zealous assistance rendered him by the members of his party.

In addition to the acknowledgments of cordial assistance received by the *Carnegie* party which have been made elsewhere, mention should be made of the courtesies extended by the following: Admiral Francisco Neff, of the Talcahuano navy yard; the governor of the Falklands, Hon. W. L. Allerdyce; Mr. Harding, manager of the Falkland Islands Company; the governor of St. Helena, Major H. W. Cordeau; the American consul at Bahia, Mr. D. B. Birch; Messrs. Wilson Lloyd Fox and Ackland, of the Cornwall Polytechnic Society; Mr. J. B. Phillips, of the Falmouth Meteorological Observatory; Mr. Spry, of Falmouth; Dr. W. N. Shaw, director of the London Meteorological Office; and Dr. R. T. Glazebrook, director of the National Physical Laboratory.

LAND WORK.

Africa.—During the period November 1 to the middle of December 1912, Observer W. H. Sligh was engaged at Algiers in completing the arrangements for the Trans-Saharan Expedition, making magnetic observations at the Algiers Observatory at Bouzareah, and closing the field-work in his charge. Leaving Algiers December 15, he reported in Washington on January 6, 1913, where he carried out the necessary observations for the comparisons of his instruments with the Department standards.

Observer D. W. Berky, with his chief assistant, Observer H. E. Sawyer, and party left Biskra, Algeria, for the Trans-Saharan Expedition on October 29, 1912. The caravan, as finally organized, left Ouargla on November 20 and arrived without mishap at In-Salah on December 24. After the observational work and the necessary details in connection with the business of the expedition had been completed, the party left In-Salah on January 2, for the more difficult portion of the expedition. The French post, Fort Motylinski, was reached on February 10, and, after resting of party, the expedition was resumed on February 15 and arrived without serious mishap at the Sudanese military post Kidal on March 27; here a wait of about two weeks occurred on account of delay in the arrival of the military escort and because of unsettled conditions. The party left Kidal on April 10 and reached the Niger River at Gao on April 19. From this point the observers traveled by canoe to Timbuktoo, where they arrived on May 12. Observations were made at 72 stations en route from Biskra to Timbuktoo. Between the date of arrival at Timbuktoo and July 21, the party was engaged in disbanding the caravan, computing and dispatching the observations, and making the necessary preparations for the extension of the work

On July 21 Mr. Berky resumed the observational work along the Niger River into Nigeria and Dahomey. Mr. Sawyer left Timbuktoo at the same time for Dakar, Senegal, where he arrived towards the end of October, having made magnetic observations at a number of points in Senegal. The work, both along the Niger and the Senegal Rivers, was greatly retarded owing to the exceptionally low stage of the water. The total number of stations during the fiscal year will be about 130, and will include a number of valuable secular variation stations. This important work in Africa has been greatly facilitated by the very cordial and prompt assistance rendered by the French and English governments.

At the end of the year, Mr. W. F. Wallis, one of the most experienced magneticians of the Department, was en route to Tripoli to take charge of the magnetic survey work in North Africa.

Australasia.—The general magnetic survey of Australasia, under the charge of Observer E. Kidson, has been considerably extended during the present year. Mr. F. W. Cox served as Assistant Observer until the end of February. Early in July Assistant Observer F. Brown reported to Mr. Kidson and has since been assisting him in the survey work. From November 1 to September 15, 72 stations were occupied: 29 in Queensland, 17 in Victoria, 34 in New South Wales, and 2 in the Federal Territory. The general magnetic surveys of New South Wales and Victoria have now been practically completed. The work from September 15 to October 31 was in

Queensland and it is expected that observations will be made at about 20 additional stations. In March, Mr. Kidson made comparisons with the magnetometer at the Red Hill Observatory and during April he compared the instruments of the Department, returned by the Mawson Antarctic Expedition, with those used by him. For reference to the magnetic work accomplished by Mr. E. N. Webb, on this expedition, see General Summary, p. 257.

Canada.—A magnetic expedition covering a little explored part of the district of Patricia was undertaken and brought to a successful conclusion under the charge of Dr. H. M. W. Edmonds, assisted by Observer D. M. Wise. A particularly interesting and important feature of this field-work was the proximity of the line of observations to the supposed region of maximum total intensity. The party left Washington May 16 for Fort William and thence to Lac Seul, where they outfitted at the Hudson Bay Company's post. With Indian canoemen and guides and two canoes they proceeded to Lake St. Joseph, observing en route. Near Osnaburgh observations were made exactly over Fawcett's post of 1885. Thence the party proceeded up Cat River to Cat Lake and a side trip was made towards the northwest to the region of supposed maximum intensity as disclosed by Lefroy's observations of 1845. The journey was continued by way of Cedar River and Windigo Lake, thence across very difficult, uncharted country to Trout Lake. From there a better-known line of travel down the Fawn and Severn Rivers brought the party on July 17 to Fort Severn, on Hudson Bay. Observations were made at 19 points on this stretch. Many portages and rapids, stormy lakes, and bad weather made the traveling hard and the party arrived at Fort Severn with provisions gone and found also empty warehouses, but the arrival of a coast steamer with supplies enabled them to make a partial provision for proceeding further.

The next portion of the trip lay along the shores of Hudson and James Bays—considered a particularly dangerous bit of canoe work, especially as the canoes of the region are shaped for inland work. This region has very seldom been traversed, even by a native, and no guides were obtainable. After leaving Fort Severn, magnetic observations were made at 8 stations along the coast and also at Fort Albany. One station occupied was at the point of separation of Hudson and James Bays. The party arrived at Fort Albany on August 31. From here the expedition was continued up the Albany River, making stops for observations about every 50 miles in a straight line till near Osnaburgh. Up this river progress was by tracking, poling, and paddling, there being many portages. Part of this journey was made during snow storms and rapid progress was necessary to reach the railroad before the freezing-up. Bad

weather prevented connecting the work on the outgoing trip with that on the return at any station till Lac Seul was again reached. From here the party returned to Fort William, where the Canadian station of 1910 was occupied, and then proceeded to Ottawa. There several sets of observations were made for the purpose of comparing the instruments of the Department with those of the Canadian Magnetic Survey. Then followed the return to Washington, where the party arrived on October 25.

The main part of the field-work comprised the canoe route of approximately 2,000 miles, of which over 500 miles was over an unsheltered open coast; 37 separate stations were occupied and 1 old station was reoccupied. It required the constant strenuous physical exertions of every member of the party to complete the trip during the open season.

South America.—Three parties have been engaged during the year in magnetic-survey work in South America. Observer H. R. Schmitt was on field duty in Peru, Bolivia, and Chile until April 26, 1913, when he reported on board the *Carnegie* for ocean duty. He occupied 12 stations in Peru, 2 in Bolivia, and 21 in Chile. During March to April he instructed and trained an observer who, it is expected, will undertake field-work for the Chilean government.

Observer A. D. Power by September 17 had occupied 31 stations in Venezuela, 1 in Colombia, 1 in Curaçao, 1 in Trinidad, and 13 in Brazil. Mr. Power was ill with fever from December 28 to January 26, but by March he had sufficiently recuperated to permit the continuation of his work and preparation for an expedition up the Orinoco River and thence to Manaos, Brazil, via the Rio Negro. He left Port of Spain, Trinidad, on May 27, and arrived safely at Manaos on August 16. From Manaos Mr. Power continued his expedition via the Rio Negro and Rio Branco, across the frontier into British Guiana, and thence via the Essequibo River system to Georgetown. His total number of stations during the year will be about 70.

Observer H. F. Johnston was relieved of duty on board the *Carnegie* on May 17 and has since continued in the field in Brazil, Argentina, Paraguay, and Uruguay. By September 9 he had occupied 6 stations in Brazil, 13 in Argentina, 11 in Uruguay, and 8 in Paraguay. During May he secured comparisons with the field instruments of the Brazilian government at Vassouras, and during June with the standard instruments at the Pilar Magnetic Observatory, Argentina. He reached Villa del Pilar, Paraguay, at the end of the fiscal year. He will continue up the Paraguay River and thence, if possible, along the Madeira and Amazon Rivers to Manaos, connecting there with the work of 1910 and with Mr. A. D. Power's series of stations. By the end of the fiscal year he had occupied 38 stations.

DETAILS OF WORK IN WASHINGTON.

ERECTION OF RESEARCH BUILDING.

The regular office work during the fiscal year had to be curtailed somewhat because of the time and attention required in connection with the erection of the research building to contain office, laboratory, and instrument shop, for which a grant of $100,000 was made by the Trustees of the Institution on December 13, 1912. Considerable time was devoted to the study of various laboratories in and outside of Washington. The data secured were summarized and such detail as seemed suitable for the building of the Department was incorporated in the preliminary plans. Mr. Waddy B. Wood was selected as architect for the building, and the final plans, with the cooperation of Mr. Fleming, were completed by him on March 27. The plans and specifications were submitted to eight first-class builders on March 29, and the competitive bids were received April 15. On April 29 the contract was awarded to the Davis Construction Company, of Washington, D. C., who were the lowest bidders. The bids, rejecting one which was manifestly in error, had an extreme range of but 10 per cent. For views of the building, see plates 8, 9, 10, 11 and 12.

The only change made in the original plans of the building was the substitution of reinforced concrete floors for structural steel construction. After a topographical survey of the site had been made, the necessary grading and the construction of a road on our grounds to the adopted site of the building was completed, under Mr. Fleming's supervision, by the Department. The Davis Construction Company began with the erection of the building on May 5; by the end of the present fiscal year the building was about two-thirds completed and it is expected that it will be ready for occupancy early in 1914.

INVESTIGATIONAL AND PUBLICATION WORK.

The proof of the first volume of the researches of the Department, "Land Magnetic Observations 1905–1910," was revised and the publication was completed, being No. 175 of the publications of the Institution. The material for the second volume of Researches, "Land Magnetic Observations 1911–1912," has been prepared and the manuscript will be ready for the printer at the end of 1913. The final computations of the data secured on the *Galilee* have been made and the preparation of the manuscript is under way. The preliminary reductions and discussions in connection with the work on board the *Carnegie* have been continued. The magnetic declinations obtained by the ocean party have been published for the cruise as far as St. Helena. The publication of the magnetic intensities and inclinations is deferred, pending the complete discussion of the instrumental constants at the conclusion of the present cruise.

The Director has continued his series of publications in the journal Terrestrial Magnetism and Atmospheric Electricity, on the physical theory of the Earth's magnetic and electric phenomena, having presented papers on the subject before various societies. In continuation of this investigation, he also completed, with the assistance chiefly of Mr. Duvall, a preliminary analysis of the general magnetic field of the Sun as revealed by the published observations at the Mount Wilson Solar Observatory.

It was found that the solar magnetic field is as complex as that of the Earth and that the distorting or disturbing systems which are superposed upon a primary, simple magnetic field, follow laws very similar to those disclosed in the study of the terrestrial magnetic field. Thus, for example, the plane containing the magnetic axis of the Sun is displaced in passing from the Northern to the Southern Hemisphere in precisely the same direction eastward (in the direction of rotation) as was found to be the case with the Earth's magnetic axis. Accordingly, to give the requisite precision to the term "magnetic axis," the region from which it is determined must be carefully stated. The magnetic axis as determined from the published data between the parallels 60° north to 60° south, for the four series of observations between January 1912 and February 1913, was found to be inclined about 9° to 12° to the axis of rotation. The same angle of inclination for the Earth was 11.6° in 1885.

The remarkably close analogies which thus appear to exist between the magnetic field of the Sun and of the Earth, coupled with the fact disclosed by Hale that "the polarity of the Sun corresponds with that of the Earth, *i. e.*, the north magnetic pole lies near the north heliographic pole," may possibly indicate, since the direction of rotation of the two bodies is the same, that the origin of both magnetic fields will have to be referred finally to similar causes. In any case, the fact that the Sun's magnetic field turns out to be as complex and as irregular as that of the Earth, and that these apparent irregularities follow similar laws for both bodies, would seem to strengthen the conclusion already reached in the investigation of the terrestrial magnetic field, that it may not be necessary to refer the cause of the non-coincidence of the magnetic axis with the axis of rotation chiefly to heterogeneity of structure of the bodies under discussion.*

An examination and recompilation of the magnetic data secured by Halley, 1698–1700, was also made by the Director, assisted by Messrs. Ault and Wallis, and articles were published giving the results. From April 21 to June 11 he was in Europe in the interests of the Department. While there he concluded the appointments of a physicist and two magnetic observers, and conferred with various men interested in the work of the Department in Germany, Sweden, and England, regarding certain cooperative work.

*For abstract, see Journal of the Washington Academy of Sciences, December 19, 1913, vol. III, p. 513.

Reductions of field observations have been kept up to date as far as time permitted, chiefly by Messrs. Fisk and Ault. Special instructions, directions, and compilations of data were prepared for the Crocker Land Expedition. The observations and magnetic results obtained by the Australasian Antarctic Expedition have been revised and prepared for publication. Detailed studies and discussions have been made of the performance of specially made watches submitted by five prominent manufacturers for use in the field. Articles describing instruments manufactured by the Department have been prepared by Messrs. Bauer, Dorsey, Fleming, and Widmer and published (see Bibliography).

Dr. Swann, after an examination of various matters submitted to him in relation to the past work of the Department in atmospheric electricity, had his attention turned to the subject of atmospheric electricity in general, especially in relation to ocean measurements.

Certain pieces of apparatus and certain methods have been devised which he hopes to submit soon to experimental trial and which are intended primarily to facilitate measurements of atmospheric electricity at sea, more particularly with a view to overcoming difficulties due to the motion of the ship. A new method of determining the atmospheric potential gradient has been proposed by him which involves measuring the velocity which it is necessary to give to a group of electrons to enable them to travel a fixed distance against the Earth's field. The method, if successful in application, will have many advantages over the usual one, more particularly in the instantaneousness of its action.

While considering the question of the measurement of the atmospheric potential gradient, Dr. Swann investigated a theory as to the connection of this quantity with certain other atmospheric electrical phenomena. In connection with this work, there was occasion to examine the usual theory of conduction in a gas between two parallel plates, and it was found that the assumptions made in the calculations are equivalent to imagining the plates to be an infinite distance apart. The corrections involved, even when the plates are close together, are not considerable, unless the rate of production of ions is small, for which case, however, they may become enormous; consequently an amended calculation of this important problem has been developed.*

INSTRUMENTAL WORK.

An investigation of methods used in the determination of the moment of inertia of magnets was made by Dr. N. E. Dorsey, who also specially examined and prepared a report on the determination of the moment of inertia of magnet H26 used at the Cheltenham Magnetic Observatory. This discussion has shown that the greater

*For fuller publication, see journal Terrestrial Magnetism and Atmospheric Electricity for December 1913.

part of the large correction of the Cheltenham magnetometer on the Department's standard was due to the adopted value of the computed moment of inertia of H26. Dr. Dorsey also prepared a preliminary design for an absolute sine galvanometer for use in the absolute determination of the magnetic intensity.

Instrumental constants and corrections on the adopted magnetic standards of the Department have been determined for four magnetometers, five dip circles, and three earth inductors. A non-magnetic lever comparator has been designed and manufactured for use in measuring magnets.

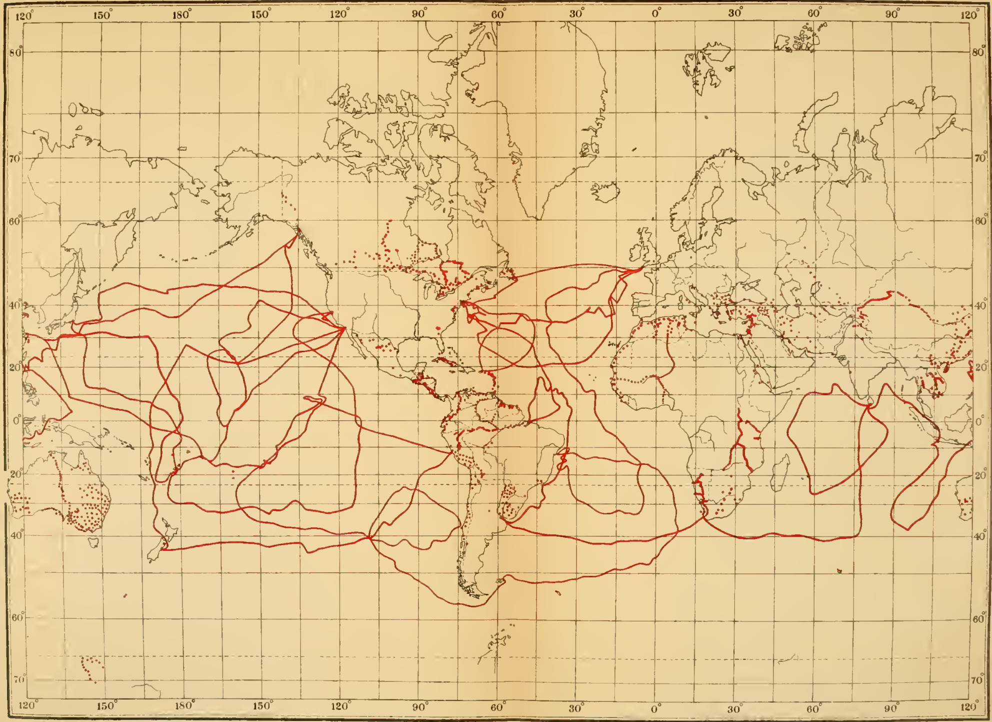
Owing to the difficulties generally experienced in the satisfactory determination of the corrections of dip needles to standard and the possible changes in these corrections with geographical variation in magnetic intensity and inclination and with wear of pivots of the needle, it was found desirable to further improve the universal magnetometer of the Department by replacing the dipping needle by an earth-inductor attachment. Accordingly a combined magnetometer and earth inductor has been designed by Messrs. Fleming and Widmer and constructed in the instrument shop. The instrument consists essentially of four parts: (*a*) the base, (*b*) the magnetometer attachment, (*c*) the earth inductor and theodolite attachment, and (*d*) the galvanometer. The effort has been to secure a compact, portable instrument, with a minimum of loose accessories, for rapid field work of high precision. A galvanometer of the Kelvin type has been specially designed for this instrument. One of these magnetometers has been completed and two others are under construction. (For the article by Messrs. Fleming and Widmer describing the combined magnetometer see Bibliography.)

Universal magnetometer No. 22 of the 1910 type has been completed and forwarded on order to the Imperial University of Kazan, Russia; magnetometer and earth inductor No. 23 of the new design has been similarly forwarded to the Physical Laboratory of the Technological Institute at Tomsk, Siberia. Earth inductor No. 4 has been completed and supplied to the Royal Alfred Observatory at Mauritius.

PERSONNEL.

The personnel during the year was as follows:

L. A. Bauer, Director; N. E. Dorsey, Research Associate (to March 12); W. F. G. Swann, consulting physicist (June 1–September 28) and chief physicist (from September 29); J. A. Fleming, chief magnetician; W. J. Peters, in command of the *Carnegie;* H. M. W. Edmonds, H. W. Fisk, J. P. Ault, and W. F. Wallis (from July 1), magneticians; C. R. Duvall, expert computer (from October 11); C. C. Craft, surgeon and magnetic observer aboard the *Carnegie;* C. W. Hewlett, assistant physicist; E. Kidson, W. H. Sligh (to March 1), H. F. Johnston, D. W. Berky, H. E. Sawyer, H. R. Schmitt, A. D. Power, A. H. Palmer (from February 4 to October 8), D. M. Wise (from April 15), W. C. Parkinson (from June 1), magnetic observers; F. W. Cox (to February 28) and F. Brown (from May 30), assistant observers; C. K. Edmunds (occasional magnetic-survey work in China).



THE MAGNETIC WORK OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM, 1905–13.

ARCHEOLOGY.

Frothingham, A. L., Princeton University, Princeton, New Jersey. Grant No. 792, allotted January 18, 1912. *Preparation of memoir on memorial and triumphal arches in Rome and throughout the Roman Empire, comprising study of Arch of Constantine, the arches of Verona and Rimini, the triumphal arch at Aquinum, and the colony arch at Privernum.* $750

The scope of Professor Frothingham's work was the continuation of his study of Roman triumphal arches and monumental city gates in Italy. Among unexpected results were:

(1) The identification of a hidden double gateway at Rimini as the main city gate of the original Roman frontier colony of Ariminum, founded in 268 B. C., and therefore the earliest known Roman city gate.

(2) The discovery of extensive remains of the Forum and Capitoline temple of Verona, a discovery which will revolutionize the topography of this important Roman city, because their location even had not hitherto been suspected, whereas now a partial reconstruction of their scheme will be possible.

(3) The fact that the hidden inner façade of the city gate of Verona, called Arco dei Leoni, instead of being a work of the late Empire, is a rare piece of late Hellenistic architecture of pre-Augustan or early Augustan date.

The most detailed investigation was that of the Arch of Constantine in Rome in connection with Professor Frothingham's contention that it was not built by Constantine, but had existed for more than two centuries before his time, having been built by the Emperor Domitian. When Domitian was assassinated and his memory damned by the Senate, many of his monuments were destroyed or mutilated, and it was then that this arch was dismantled, to be restored more than once and used as a generic triumphal arch during the third century, until it was finally rededicated to Constantine. In the course of these transformations, sculptures were inserted into the body of the arch or carved on it. Through the kindness of the Italian Ministry of Fine Arts scaffolds were built which made it possible for Professor Frothingham to examine minutely, in a way never done before, every stone and sculpture of the arch from top to bottom, to make all the casts, photographs, measurements, and architectural drawings necessary for a complete illustration of the arch and the elucidation of its problems. Preliminary reports were presented to the International Archeological Congress in October 1912, but the work was not completed until May. The results are in course of publication in the American Journal of Archæology, and these articles will be followed by a fuller monograph.

Casts and photographs were also made of parts of the arch of Augustus at Rimini, of the double city gate at Ascoli Piceno, of the Janus arch of the Velabrum at Rome, and of the arch of Augustus at Fano. The medallion sculptures of the Rimini arch, two of which were cast, have never been studied, though they are of almost unique interest for the rise of Roman sculpture, because they can be exactly dated in 27 B. C., early in the reign of Augustus, and are masterpieces of the Hellenistic school. The double gate at Ascoli is the only well-preserved example of the Porta Gemina, such as existed at Rome and elsewhere in Central Italy in the late Republic, and of which an earlier instance was noted above at Rimini. At Fano it was ascertained that the superstructure and gallery of the Augustan gate, though restored by Constantine, was not, as has been supposed, of Constantinian but of Augustan construction. Near Rome the structure of the heavy Janus arch of Saxa Rubra, of the time of Diocletian or Constantine, which has not yet been thoroughly studied, was investigated for stamped tiles by which it might be exactly dated.

Further study was made of arches and gates in northern and central Italy, at Verona, Ravenna, Capua, Spoleto, Perugia, Aquino, Piperno, and Terracina. For comparative purposes the Arch of Titus, the Forum of Nerva, the Colosseum, and other imperial structures were examined, particularly in relation to the dating of various parts of the Arch of Constantine. The casts of the latter arch were placed in the museum of the Roman Forum.

Two side-issues were necessarily a part of these studies: (1) the character and historic succession of Roman stone masonry, brick-work, and concrete, as giving the key to the age of undated arches and gates; and (2) Roman relief sculpture, ornament, and moldings, in connection with the decoration, purpose, and character of this class of structures and as often the only remaining proof of their existence.

An example of the value of the norms which Professor Frothingham is gradually establishing is the proof that the Capitoline Temple of Aquino is a valuable work of the late Republic.

As a third side-issue, collections of drawings of Roman arches and their sculptures made during the Renaissance were examined, together with the notes that often accompanied them. The collections at Siena and Florence are particularly rich. A considerable number of negatives were made of such drawings existing in the Royal collection at Windsor and dating from the fifteenth, sixteenth, and early seventeenth centuries. They are invaluable in giving data about arches since destroyed or mutilated and for reproducing lost bas-reliefs. They also show how strongly Renaissance architects and sculptors were influenced by Roman triumphal arches; more, perhaps, than by any other single class of ancient monuments.

A last and unfinished piece of work was in connection with the main city gate at Ostia. This triumphal gate, first built in the late Republic, then refaced and redecorated under the Middle Empire on a higher level, has been recently excavated and enough of its structure and decoration found to make an ideal reconstruction possible. The director of the excavations, Professor Dante Vaglieri, has requested Professor Frothingham to direct this reconstruction, placing two of his assistants at his disposal for this purpose.

Van Deman, Esther B., Rome, Italy. Grant No. 843, allotted December 13, 1912. *Research Associate in Roman archeology.* (For previous reports see Year Books Nos. 9–11.) $1,800

During the fall and early winter of 1912–13 but little new work was undertaken. The greater portion of the time, after the conclusion of the International Congress of Archeology, which was held in Rome in October, was given instead, (1) to the preparation of a special bibliography for the various monuments, as well as to an examination of the more important collections of early prints in which the ancient buildings are represented; and (2) to the identification and classification, by means of the data thus obtained, of the more important monuments in the different regions which are now destroyed or inaccessible. The latter part of the year was devoted, in large part, to the regular work on the methods of concrete construction, with a view especially to the completion of the data necessary for the publication, as soon as possible, of a fuller and more exact canon or norm of construction.

The discovery, during the year, of a large number of new walls of the time of Nero, in the vicinity of the Colosseum, as well as of the more extensive remains under the so-called domus Augustana on the Palatine, with the interesting study of the frescoes of the domus Aurea made by De Weege, of the University of Bonn, has led to a new and more general interest in the work of that period. The time has seemed opportune, therefore, not only for the more thorough study of the many remains of the period in other parts of the city, but especially for the completion and publication, as soon as possible, of the extensive plan, begun several years since, of the Neronian remains on the Velia.

With the kindly assistance of Dr. Thomas Ashby, Director of the British School in Rome, whose exhaustive work on the aqueducts is soon to appear, a special investigation has been begun of the problems, both structural and chronological, presented by the Claudian and the Marcian Aqueducts. As a result of this merely preliminary examination, it has been possible not only to determine more definitely the extent of the various restorations already recognized, but also to assign to the time of Hadrian extensive remains not before

identified. In connection with this investigation, a special study has been made of the different types of construction employed in the dated monuments of the Hadrianic period.

The more important of the individual monuments inside the city, to which especial attention has been given during the year, are the domus Tiberiana on the Palatine, the so-called Temple of Augustus, and the porticus of Gaius and Lucius in the Forum, concerning the last of which a discussion appeared in the March number of the American Journal of Archæology. Owing to the more urgent claims of the work near at hand, it has not been possible to continue the systematic study of the important monuments brought to light by the recent excavations at Ostia, which was begun during the last year. Considerable time has been devoted, however, to an examination of the remains at Porto of the port of Ostia, built by Trajan, as an aid in determining the date of a number of the more important monuments in Ostia itself.

The months of March and April were spent in a general examination of the extensive Roman remains in North Africa. The most important points visited in Tunis were Carthage, Susa, El Djem, Sbeitla, Thelepte, Dougga, Bulla Regia, and Smitthu, while in Algiers, though the greater part of the time was devoted to Lambese and Timgad, brief visits were made also to Tebessa, Guelma, Constantine, Biskra, Algiers, Guyotville, Cherchel, and Tipasa. The remains seen, though often impressive on account of their vast extent and size, are conspicuous for their lack in structural finish. It is clear from their technique that in the erection, even of the great monuments, native workmen and methods were almost wholly employed. From the prevalence of concrete construction, as well as from its appearance in many early monuments, it seems possible that the knowledge of its use antedated the Roman domination. Many valuable data for the study of the early Roman construction were gathered from an examination of the buildings made of sun-dried brick in southern Algiers.

BIBLIOGRAPHY.

Garrison, Fielding H., Army Medical Museum, Washington, District of Columbia. Grant No. 868, allotted December 13, 1912. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–11.) $12,500

During the past year (1912–13), the medical profession and the Carnegie Institution of Washington have sustained a severe loss through the deaths of the founders and original editors of the Index Medicus, Dr. John S. Billings and Dr. Robert Fletcher. Dr. Fletcher died at Washington, D. C., on November 8, 1912, at the age of 89,

and four months later, at the age of 75, Dr. Billings died in New York City, on March 11, 1913. Obituary records of their lives and life-work will be found in the Index Medicus for December 1912 and March 1913, respectively.

In spite of every effort to limit the amount of material, the increase in number of medical and scientific periodicals has been such that the Index Medicus for 1912 contains 1,409 pages, an advance of 52 pages over the issue for 1911. The annual index for 1912, however, contains 224 pages, which is 4 pages less than that of 1911. This is explained by the fact that the classification of the Annual Index for 1912 has been materially condensed by the omission of superfluous or unimportant subtitles.

During the year 1912–13, the subject "Metabolism" has been specialized under "Physiology," because, in connection with the modern doctrine of internal secretions, the titles relating to this subject are beginning to take on a more definite aspect, and the literature of both subjects is increasing in bulk. For reasons of a similar character, the subject of "Mycoses" has been added, and the diseases "beri beri" and "pellagra" have been grouped in the class "Intoxications."

CHEMISTRY.

Acree, S. F., Johns Hopkins University, Baltimore, Maryland. Grant No. 829, allotted December 13, 1912. *Continuation of the study of catalysis and tautomerism.* (For previous reports see Year Books Nos. 4–11). $2,000

During the last eight years (1905–1913) our studies on catalysis and the mechanism of organic reactions have shown conclusively that both the ions and the nonionized forms of acids, bases, and salts must be tested for chemical activity in all their reactions. This theory has not only been placed on a secure footing by our own work, but has now been adopted by Arrhenius, Goldschmidt, Bredig, and Stieglitz, and used in interpreting their data. During the past year the writer has published articles describing the work by his collaborators, Dr. H. C. Robertson jr., Dr. E. K. Marshall, jr., Dr. Julia Peachy Harrison, Dr. C. N. Meyers, Dr. F. M. Rogers, and Dr. Sidney Nirdlinger, on the reactions of alkyl halides with sodium, potassium, and lithium ethylates, with sodium, potassium, and lithium phenolates, and with sodium phenyl thiourazole, and on the reversible addition of alcohols to nitriles in the presence of sodium, potassium, and lithium ethylates. The effect of added neutral salts on all these reactions has been especially investigated.

In all these cases it has been found that both *the ethylate or phenolate anion* and *the nonionized ethylates or phenolates react*, and that

the total reaction velocity must be expressed by the following equations, for example:

$$C_2H_5I+\bar{O}C_2H_5-(C_2H_5)_2O+$$
$$C_2H_5I+NaOC_2H_5-(C_2H_5)_2O+NaI, \text{ or}$$

$$\frac{dx}{dt}=K_t\alpha(C_{salt}-x)(C_{alkylhalide}-x)+K_m(1-\alpha)(C_{salt}-x)(C_{alkylhalide}-x)$$
$$=[K_t\alpha+K_m(1-\alpha)](C_{salt}-x)(C_{alkylhalide}-x)$$
$$=K_V(C_{salt}-x)(C_{alkylhalide}-x).$$

Solutions varying in concentration from N/1 to N/2048 were used in testing the theory. The resulting simultaneous equations, $VK_V=K_N=K_t\alpha+K_m(1-\alpha)$, were solved for K_t and K_m, which are the reaction velocities of a gram ion of ethylate ions, for instance, and a gram molecule of sodium ethylate molecules, with a gram molecule of the alkyl halide, in one liter.

There is a wide variation in K_N and α, but the values for K_t and K_m are quite constant. A very important substantiation of the theory is the fact that the same value for K_t, for the ethylate or phenolate ion, is obtained whether we work with the sodium, potassium, or lithium salt. These salts all have different ionization values and different reaction velocities, but they yield the same anion, which should and does have the same activity, whatever its source. The nonionized sodium, potassium, and lithium salts, however, are different substances, and have different reaction velocities. It has been found that the reaction velocities of the nonionized sodium, potassium, and lithium salts increase in the order of their affinity constants, a principle found by Bredig to hold in the application of this theory to his work. A hypothesis to account for this phenomenon in terms of the electron theory has been developed.

A large amount of work on the "salt catalysis" produced by added salts has shown that these exert the "normal salt effect" arising from the changes in ionization demanded by the Arrhenius isohydric principle, and in some cases bring about an added positive or negative "abnormal salt catalysis," which is thought tentatively to be due to double salts and electronic phenomena.

On the reaction of ethyl iodide with sodium 1–phenyl–3–thiourazole. By Sidney Nirdlinger, F. M. Rogers, and S. F. Acree, American Chemical Journal, 49, 116.

In this article is presented the work of Dr. Nirdlinger and Dr. Rogers, finished in May 1908, on the reaction of ethyl iodide with sodium–1–phenyl–3–thiourazole. The results prove conclusively that *both* the urazole anion and the nonionized urazole salt react with the alkyl halide, the values $K_t=0.435$ and $K_m=0.17$ having been obtained. These figures are in substantial agreement with the values $K_t=0.465$ and $K_m=0.16$, obtained by Dr. J. Chandler, who has repeated the work under somewhat better experimental conditions.

On the reversible addition of alcohol to nitriles catalyzed by ethylates. By E. K. Marshall, jr., and S. F. Acree. American Chemical Journal, 49, 127.

Dr. Marshall has shown that the twelve nitriles studied by us do not add alcohols, and the imido esters do not lose alcohol with any appreciable velocity, unless catalyzed by sodium, potassium, lithium, thallium, or other ethylates. The reaction has been found reversible in every case studied, and the equilibrium point is the same, whether measured from the nitrile or from the imido ester, although disturbing side reactions make the agreement in some cases less satisfactory than desired. The equilibrium point varies widely with the different compounds, the percentage of imido ester formed being illustrated by the following examples: butyronitrile, 0.90; propionitrile, 1.75; acetonitrile, 2.50; *p*–tolunitrile, 6.8; benzonitrile, 14.0; *p*–brombenzonitrile, 27.2; *m*–brombenzonitrile, 38; *p*–nitrobenzonitrile, 62.0; *m*–nitrobenzonitrile, 78.0; diisoamylcyanoamide, 98.0. A few of these experiments given in this article and in other unpublished work show that the reaction velocity can be expressed as a function of the concentration of both the ethylate ions and the nonionized salts.

On the reactions of both the ions and the non-ionized forms of electrolytes. By S. F. Acree. American Chemical Journal, 49, 345.

In this article is presented a large amount of original material and a reinterpretation of the work of Arrhenius, Ostwald, Goldschmidt, Bredig, Stieglitz, Holmberg, van Dam, Koelichen, and others, who had assumed that only the ions are chemically active. It is shown that the discrepancies in their work and theories can be accounted for very easily by our theory that, in all these cases, the activity of both the ions and the non-ionized electrolytes must be considered. A large number of calculations are given in support of the newer point of view.

On the reactions of both the ions and the nonionized forms of electrolytes. The reversible addition of alcohol to nitriles catalyzed by sodium ethylate. By E. K. Marshall, jr., Julia P. Harrison, and S. F. Acree. American Chemical Journal, 49, 369.

In this article is given an accurate quantitative study of the velocity of the reversible decomposition of acetimido ethyl ester and benzimido ethyl ester into ethyl alcohol and the corresponding nitriles at 25° in the presence of sodium ethylate in varying concentrations. The data show clearly that the reaction velocities can be expressed as a function of the concentrations of both the ethylate ions and the nonionized sodium ethylate. We obtained for benzimido ethyl ester the values $K_i=0.1172$ and $K_m=0.0976$, and for acetimido ethyl ester the constants $K_i=0.344$, and $K_m=0.288$.

A recalculation of the work of Stieglitz and Schlesinger on the decomposition of imido esters by barium hydroxide shows that their theory, that only the hydroxyl ions act catalytically, is untenable,

and that their work substantiates our theory that both the hydroxyl ion and the nonionized barium hydroxide may be considered active.

A large amount of data on the velocity of decomposition of benzimido ethyl ester and acetimido ethyl ester by sodium ethylate in the presence of sodum iodide and sodium bromide shows that the "salt catalysis" produced by the sodium iodide *in this case* is due simply to the change in the percentage of ionization of the sodium ethylate by the sodium iodide. In accordance with the Arrhenius isohydric principle, the sodium iodide changes the percentage of ionization of the sodium ethylate; since the ethylate ions and nonionized sodium ethylate do not have the same activity, there is a change in the reaction velocity. Although the "salt effect" *in this case* is apparently simple, other unpublished data show that in some cases it is far more complex.

On the reactions of both the ions and the nonionized forms of electrolytes. The reactions of sodium phenolate with methyl iodide and ethyl iodide in absolute ethyl alcohol at 25° and 35°. By H. C. Robertson, jr., and S. F. Acree. American Chemical Journal, 49, 474.

Dr. Robertson obtained a large amount of quantitative experimental material in his study of the reactions of methyl and ethyl iodides with sodium phenolate at 25° and 35°. All of the experimental methods, the purification of the materials, the apparatus, the methods of calculation, and the quantitative data are given fully. The results show very clearly that both the phenolate ions and the nonionized sodium phenolate must be reacting with the alkyl halides studied. We have obtained the values $K_i = 0.0282$, and $K_m = 0.00474$ for sodium phenolate and methyl iodide at 25°, $K_i = 0.091$ and $K_m = 0.0131$ for sodium phenolate and methyl iodide at 35°, $K_i = 0.0056$ and $K_m = 0.00099$ for sodium phenolate and ethyl iodide at 25°, and $K_i = 0.0184$ and $K_m = 0.00323$ for sodium phenolate and ethyl iodide at 35°. A discussion of "normal" and "abnormal salt effects" is given.

Baxter, Gregory P., Harvard University, Cambridge, Massachusetts. Grant No. 888, allotted May 15, 1913. *Determination of atomic weights.* (For previous reports see Year Books Nos. 3–11.) $1,500

With the assistance of the above grant, the following researches were carried on under Professor Baxter's direction:

The investigation upon the atomic weight of lead through the analysis of lead bromide, begun some time ago by Mr. Worsham and Dr. Thorvaldson (see Year Books Nos. 8 and 9), was continued by Mr. F. L. Grover. The salt was fused in atmospheres containing varying amounts of hydrobromic-acid gas and in some cases a small amount of bromine vapor. Then it was dissolved and the bromine content determined either by comparison with silver or as silver bromide in the usual way. Hydrolysis during solution with formation of an insoluble basic bromide was prevented by acidifying slightly

the water in which the salt was dissolved. While the research is not yet completed, the results so far obtained vary very little from an average of 207.16 (Ag = 107.88) for the atomic weight of lead. This value is somewhat higher than that previously found by Dr. Wilson in a similar way by analysis of lead chloride 207.10 (see Year Book No. 6). Both investigations, however, agree in yielding results over two-tenths of a unit higher than Stas's earlier one.

In order to supplement the work concerning the atomic weight of neodymium (see Year Books Nos. 8, 9, and 11), very pure praseodymium chloride has been prepared and analyzed. Crude double nitrate of praseodymium and ammonium, kindly loaned by the Welsbach Light Company, has been purified by fractional crystallization through the efforts of Messrs. Whitcomb, Grimes, Wallace, and Stewart. Nearly 4,000 crystallizations have been made in series of about 25 fractions, the extreme fractions being occasionally rejected. In this way neodymium was completely eliminated from certain fractions so far as spectroscopic examination could determine. Mr. O. J. Stewart has already converted to anhydrous chloride and analyzed the purest fractions. As in the case of neodymium chloride, praseodymium chloride seems to be converted into an insoluble modification by prolonged heating above the fusing-point. The fractions examined up to the present time agree in yielding, as the atomic weight of praseodymium, a value not far from 140.92. This value is three-tenths of a unit higher than the one adopted by the International Committee on Atomic Weights.

Nearly 4 kilograms of cæsium nitrate extracted last year from Maine pollucite has been subjected to prolonged fractional crystallization in a search for a strange element of the alkali family. As might be expected from previous investigations this search was unsuccessful. The extreme fractions when examined spectroscopically showed no new lines and were not sensibly radioactive.

Work has also been continued on the atomic weights of arsenic and neodymium and on the change in volume which takes place during the solution in water of certain salts.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. Grant No. 847, allotted December 13, 1912. *Continuation of investigations on the absorption spectra of solutions and on the conductivity and dissociation of electrolytes in water and in nonaqueous solvents at different temperatures.* (For previous reports see Year Books Nos. 2–11). $2,200

The work on the absorption spectra of solutions, using the radiomicrometer, has been carried out during the year by J. S. Guy and H. C. Jones, with the assistance of E. J. Shaeffer. The work during the first half of the year had to do with the relative absorption of light by pure water, and by an equal amount of water in the presence of a dissolved substance. In a word, does the dissolved substance have any effect on the power of the solvent to absorb light?

The following rather surprising result was obtained: Pure water of a certain depth of layer was found to be *more opaque* for certain wave-lengths than an equal depth of water in a solution of a salt like calcium chloride, while pure water had the same absorption as an equal depth of water in a solution of potassium chloride. Why this difference?

Calcium chloride is a strongly hydrated salt, while potassium chloride is scarcely hydrated at all; and this suggested a possible explanation for this result. A number of strongly hydrated compounds were studied, and also a number of compounds which combine with very little of the solvent when they are dissolved in it. The solvent was generally more opaque than the water in the solution, whenever it was a solution of a strongly hydrated salt. Whenever the salt was only slightly hydrated, the pure water and the water in the solution had the same absorption. This would indicate that the water combined with the dissolved substance had less, in general, absorption than pure, uncombined water. The above fact is regarded as evidence that there is combination between the solvent and the dissolved substance.

During the second half year the work upon the absorption spectra of solutions by means of the radiomicrometer had to do with the mapping of the infra-red spectra of solutions of salts of cobalt, nickel, praseodymium, and neodymium. The results of all of this work have been published as monograph No. 190 by the Carnegie Institution of Washington.

The study of the conductivity of solutions of salts in mixtures of ethyl alcohol and water has been continued during the year by Dr. E. P. Wightman, Dr. P. B. Davis, and Mr. August Holmes. They made a careful and fairly exhaustive study of solutions of potassium iodide and sodium iodide in the above-named solvents, both from the standpoint of conductivity and of viscosity. Both the conductivity and viscosity methods were improved, and a new method worked out for preparing the mixed solvents of a given concentration of the one in the other. Several dilutions of potassium and sodium iodides in the various mixtures were studied, and the data obtained plotted in the form of curves. The presence of these iodides greatly increases the viscosity of the mixed solvents, especially between 100 per cent and 60 per cent alcohol. It was found that the conductivity of the salt continually decreases in passing from pure water to pure alcohol. With rise in temperature there is a breaking down of the slightly hydrated ion and a small increase in the temperature coefficients of conductivity. In alcohol the temperature coefficients are linear, which means that there is little or no alcoholation. With rise in temperature both the conductivity and fluidity curves tend to become more nearly linear.

The study of the conductivities and viscosities of solutions of electrolytes in pure and mixed solvents was extended to acetone as a solvent, and to mixtures of acetone and water, by Dr. Davis and Dr. Hughes. The salts investigated were the chloride, bromide, iodide, and nitrate of rubidium. These salts were chosen because of the large atomic volume of rubidium; and acetone was selected as the solvent because it so frequently manifests abnormal behavior and gives abnormal results. Acetone was chosen for viscosity work because it has comparatively small viscosity—glycerol, with very large viscosity, having already been studied for some years past. These salts could not be studied in pure acetone on account of their comparative insolubility. They were, however, investigated in mixtures of acetone and water. The salts of rubidium were found to increase the viscosity except in those mixtures containing the largest per cent of water. The iodide and nitrate of rubidium, which produced the greatest lowering of the viscosity of mixtures of glycerol and water, actually raised the viscosity of mixtures of acetone and water until a 5 per cent acetone mixture was reached. These same salts showed a diminution in viscosity in mixtures containing only a little acetone. They seem to have no effect on the viscosity of a mixture of 50 per cent acetone and 50 per cent water. When there is more than 50 per cent acetone present, they increase the viscosity of the mixed solvent in which they are dissolved. Rubidium salts give minima in the conductivity curves in a higher percentage of acetone than the minima in the fluidity curves. For some salts those two curves run parallel. The temperature coefficients of conductivity and of fluidity are about what would be expected.

The work on the conductivity, dissociation, and constants of the organic acids in water was extended during the year by Dr. L. D. Smith. He worked with a fairly large number of somewhat uncommon acids, at various dilutions and temperatures. Relations of interest, and it is hoped of some value, were established.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. Grant No. 830, allotted Dec. 13, 1912. *Measurement of the osmotic pressure of solutions.* (For previous reports see Year Books Nos. 2–11). $4,000

It has been shown in earlier reports with respect to all solutions of cane-sugar ranging in concentration from 0.1 to 1.0 weight-normal:

(1) That the ratio of the observed osmotic pressure to the calculated gas-pressure of the solute is constant for each concentration between 0° and 25°, which indicates that the law of Gay-Lussac for gases holds between these temperatures.

(2) That between 0° and 25° the osmotic pressures are not proportional to the supposed concentration of the solutions, which leaves the applicability of the law of Boyle in doubt.

(3) That between 0° and 25° the osmotic pressure is, in all cases, greater than the calculated gas-pressure of the solute, which suggests a concentration of the solutions through a hydration of the solute and may, therefore, explain the apparent nonconformity between these temperatures of osmotic pressure to the law of Boyle.

(4) That somewhere between 25° and 30° the ratio of osmotic to gas pressure, which between 0° and 25° is greater than unity but constant for each concentration, begins to decline—rapidly in the more dilute and less rapidly in the more concentrated solutions, as if hydrates were dissociating and the solutions were becoming more dilute in consequence.

(5) That this decline in ratio continues with rising temperature until, at some temperature which is characteristic for each concentration of solution, it becomes unity, which shows that at these temperatures the osmotic pressures of all the solutions are conforming both to the law of Gay-Lussac and to that of Boyle.

The temperature at which the ratio became unity in the most dilute solution (0.1 weight-normal) was 30°, while that at which it became unity in the most concentrated solution (1.0 weight-normal) was 80°. The unit ratio for each of the intermediate concentrations was reached at some temperature between 30° and 80°.

It was considered very important to measure the osmotic pressure of all ten concentrations of solution at temperatures between those at which the ratios became unity and the boiling-point of the solvent, in order to ascertain if the unit ratio, once reached, persists through all the higher temperatures. All possible preparations were made to meet the extraordinary difficulties which are experienced in measuring osmotic pressure at high temperatures, and it was expected to resume the work in September 1913 where it had been discontinued at the end of the previous June. It was found in the fall, however, that the membranes in all of the cells which had been used at temperatures above 40° had deteriorated during the summer and were unfit to measure osmotic pressure at high temperatures. This deterioration was a surprise, because it had been found in all previous work that the quality of the membrane was improved by the summer soaking in pure water, *i. e.*, water *free from electrolytes*, an effect which we have ascribed to an improvement in their colloidal character. Three months were spent in endeavoring to bring the membranes again into good condition. All the modes of treatment which had been found efficacious for membranes used at moderate temperatures only were employed, but without success. It was finally decided to discard all of the cells which had been used at high temperatures the previous year and to make new ones for the continuation of the work.

The mere making of the cells—involving the preparation of the clays, also the pressing, the shaping, the burning, the grinding, and

finally the glazing operation—consumes considerable time; but by no means as much as the building up and "training" of the new membranes. In order to secure a membrane which will render satisfactory service at high temperatures, it is necessary first to deposit and perfect it at some lower temperature, *e. g.*, 25°, then to reinforce and "train" it at each successive higher interval of 5° or 10°. The membranes in the new cells have already been perfected at 30°, and at this temperature they are being employed for the measurement of the osmotic pressure of glucose. It is intended to determine the pressures of glucose solutions at each higher interval until the temperatures are reached at which the work on cane-sugar was discontinued, and afterwards to investigate both substances. The cells will not again be allowed to rest at ordinary temperature until the high-temperature measurements on both glucose and cane-sugar are completed.

It was found in the case of glucose at 30° that the ratio of osmotic to gas pressure is unity, showing that at this temperature the osmotic pressures of the solutions conform to the laws of Boyle and Gay-Lussac for gases. Three series of measurements of the osmotic pressures of glucose had previously been made—one at 0°, another at 10°, and a third at about 25°. The ratios found were approximately 1.06, 1.03, and 1.00 respectively. The high ratio at 0°, which diminishes with rising temperature and becomes unity at 25°, suggests also in the case of glucose an unstable hydration of the solute.

The osmotic pressure of a series of solutions of mannite have also been measured at 30° during the past year. At this temperature, as in the case of glucose, the ratio of the observed osmotic to the calculated gas-pressure of the solute was found to be unity.

The investigation of electrolytes has been continued. Much incidental evidence had accumulated in past years to the effect that bodies of this class act injuriously upon osmotic membranes, robbing them of their semipermeable character. It was, therefore, apprehended that the direct measurement of the osmotic pressure of electrolytes would be exceedingly difficult, if not quite impossible. An investigation was first made of the action of potassium salts upon membranes consisting of copper and nickel ferro-cyanides, and it was found that the effect of these salts upon the membranes is exceedingly deleterious—probably more so upon the nickel than upon the potassium compound. It seems probable at the present time, however, that we shall be able to measure satisfactorily the osmotic pressure of dilute solutions of potassium salts, but not of concentrated ones. The deleterious effect of electrolytes appears to be ascribable to the action of the cations upon the colloidal state of the membrane material—the colloidal state being apparently essential to semipermeability in the ordinary sense. It was, therefore, surmised that the lithium cation, which is supposed to carry with it a large "atmosphere

of water," would be found less destructive to the membranes than the potassium cation. The surmise proved to be correct, and we were able to measure satisfactorily the osmotic pressure of a large series of solutions of lithium chloride. In one "endurance test" under a constant osmotic pressure of nearly 19 atmospheres, the membrane gave no evidence of deterioration until after 112 days.

In regard to the magnitude of the osmotic pressure of solutions of lithium chloride, it is to be stated that it was found to be somewhat larger than would have been anticipated from the dissociation of the salt as determined by the conductivity method.

Dr. Frazer and Dr. Holland, both of whom may be said to have grown up with, and into, this investigation, have given their whole time to the problems mentioned above; the former to mannite and to the electrolytes, and the latter to glucose and to the preparation of new cells for the resumption of the high-temperature work on cane-sugar. In the capacity of volunteer, Dr. J. B. Zinn has contributed materially to the progress made during the past year.

Noyes, Arthur A., Massachusetts Institute of Technology, Boston, Massachusetts. Grant No. 848, allotted December 13, 1912. *Researches upon the properties of solutions in relation to the ionic theory.* (For previous reports see Year Books Nos. 2–11). $3,000

During the past year an extended article on "The Relation between the Concentration and Conductance of Electrolytic Solutions" has been published by Dr. C. A. Kraus and Dr. W. C. Bray (Jour. Amer. Chem. Soc., 3, v. 35, pp. 1315–1434, 1913.) This article consists in a critical study of existing conductance data in a great variety of solvents. This study, which has established the important principle that, in all the solvents where the data enable any conclusion to be reached, the ionization of uniunivalent salts changes with the concentration in accordance with the mass-action law, provided the ion-concentration be smaller than about 0.005 normal. The investigation has, moreover, shown that the deviations which in the case of ionized substances begin to be appreciable at only slightly higher concentrations than this can be represented in all cases by an expression of the same general form, namely, $(c\gamma)^2/c(1-\gamma)=K+D(c\gamma)^m$, in which c is the concentration, γ is the ionization, K is the mass-action constant, and D and m are other empirical constants which determine the magnitude of the deviations from the mass-action law. The work has also led to many other, more specific, conclusions.

In further confirmation of the conclusions reached in the article just referred to, new experimental work has been done by Mr. W. J. Winninghoff on the conductance of solutions of iodides in amyl alcohol and propyl alcohol.

The measurements on the vapor-pressure, specific volume, and compressibility of water at temperatures from 200° to the critical

temperature have been continued by Mr. R. D. Mailey; and the experimental work is so far advanced that it will doubtless be completed during the coming year. An analogous investigation on the thermodynamic constants of ammonia has been in progress in this laboratory for several years under the direction of Dr. F. G. Keyes. The experimental work, which involved measurements of the vapor-pressure, specific volume, compressibility, and specific heat-capacity, has now been completed and an article describing it is being prepared for publication. An important practical result of this investigation is that it will make it possible to prepare an accurate set of "ammonia tables," corresponding to the "steam tables" used by engineers, thus furnishing data much needed in the operation of refrigeration-plants. Such ammonia tables are now being computed in this laboratory.

Under the immediate direction of Professor A. A. Noyes, investigations have been carried out on the equilibrium-relations of certain important oxidizing and reducing agents in aqueous solutions, namely, of the equilibria between metallic tin and stannous chloride by Mr. E. E. Corbett, between stannous and stannic chloride by Mr. W. J. Winninghoff, and between metallic strontium and strontium salts by Mr. C. L. Burdick. The purpose of these investigations is to determine values of the oxidation-potentials which will make more complete the electromotive series of the metallic elements and enable the important dissolved oxidizing agents to be included in it.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. Grant No. 849, allotted December 13, 1912. *The determination of atomic weights and other fundamental physico-chemical constants.* (For previous reports see Year Books Nos. 2–11.) $3,000

During the past winter the Wolcott Gibbs Memorial Laboratory for Research in Physical and Inorganic Chemistry was finished and became available for work. Accordingly the apparatus previously purchased by this and preceding grants was removed to the new building early in January and work was begun there at once. The time lost during the removal was more than made up by the greater efficiency and adequacy of the new building. The investigations may be divided into seven sections.

(1) *The atomic weight of carbon:*

This fundamental datum was studied with the assistance of Charles R. Hoover, in a new way. Sodium carbonate prepared in a state of great purity by several processes was fused in a stream of carbon dioxide, and then neutralized by weighed portions of a standard solution of hydrobromic acid. Other weighed portions of this solution were precipitated with the purest silver, weighing both the metal and its bromide. Thus the equivalence between sodium carbonate on the one hand and silver or its bromide on the other hand

was established with great precision. It was found that 29.4350 grams of sodium carbonate were equivalent to 59.9168 grams of silver on the one hand and to 104.3212 grams of silver bromide on the other. The values for the atomic weight of carbon calculated from these data are almost identical, being respectively 12.000 and 12.001 if silver is taken as 107.87, or 12.005 and 12.006 if silver is taken as 107.88. It is needless to say that great care was taken at every step of the work, and a special study was made of the neutralization of the carbonates by means of indicators. It is not too much to say that this investigation could not have been carried out under the unsatisfactory conditions existing in Boylston Hall, so that the new laboratory has already begun to justify itself.

(2) *The atomic weight of sulphur:*

This investigation, carried on simultaneously with the preceding by the same assistant, C. R. Hoover, was very similar to it. Sodium carbonate prepared in the same way was exactly neutralized with the purest sulphuric acid, and the solution was then evaporated with the greatest care. The equivalence between the weight of the sodium carbonate and sodium sulphate was thus established, 27.21565 grams of the former substance yielding 36.47319 of the latter. On this basis, if sodium is taken as 22.993 and carbon 12.005, sulphur is found to be 32.059. Both these investigations were finished down to the smallest detail, and it is hoped that they will soon be published.

(3) *Compressibility of organic compounds:*

With the help of Dr. J. W. Shipley, the investigation of the compressibility of systematically related organic compounds was continued for the purpose of adding to the fullness of our knowledge as to the relationships of various properties of material. Eighteen substances were studied in detail, great pains having been taken to purify the materials. Among these were not only a variety of the simpler hydrocarbons, but also cyclohexane and cyclohexanol, from which interesting data were secured.

(4) *Thermochemical research concerning organic compounds:*

This research, a continuation of work previously reported, was taken up with the assistance of H. S. Davis. He made considerable advance in the technique of the determination, especially with regard to maintaining the temperature of the outside jacket like that within the calorimeter. This was done by delivering the acid (which warms the system by neutralizing the alkali in the environing jacket) from a peculiarly shaped pipette planned to deliver at precisely the varying rate needed—as indicated by the known temperature-time curve of the inner vessel. This device was found to facilitate greatly the conduct of the experiment as well as to increase its precision. Much time was spent also in studying the causes which prevent complete

combustion and in eliminating them. The outcome thus far seems to indicate that even the highest results previously obtained from benzene were not quite high enough. This research is still in progress and will be continued by the same assistant next year.

(5) *An automatic adiabatic calorimeter:*

With the help of G. D. Osgood a generally applicable device was perfected which establishes automatically the temperature of the environing bath of the adiabatic calorimeter. For known reactions the arrangements adopted in the previously described research answers very well, but for unknown or irregular reactions it is of course inapplicable. The arrangement now under discussion was entirely different from the other; it consisted of a very sensitive hydrogen differential-thermometer with a very delicate mercury contact. A feeble current through this contact actuated a relay which caused a stronger current to open or close a burette delivering concentrated acid into the outer vessel. In this way it was found that with due precautions the outer bath could be kept automatically not more than 0.02° apart from the temperature of the inner calorimeter, no matter at what varying rates the inner bath might change. This device bids fair to be of great service in the future.

(6) *Electromotive forces of concentrated thallium amalgams:*

This research, a continuation of work already done in this direction, was carried on during last winter by Farrington Daniels. With better apparatus than before, he obtained exceedingly consistent results concerning amalgams containing as much as 40 per cent of thallium. Not only were the electromotive forces between amalgams of different concentrations measured, but also the pure metal was studied in the same connection, and heats of solution of the metal and of various amalgams in mercury were determined. A beginning was made also in the determination of the specific heats of the various liquid and solid solutions. This research is to be continued next year, and when it is finished should present an unusually complete series of data for thermodynamic reasoning.

(7) *The electromotive forces of alkali metals dissolved in melted lead:*

With the help of W. B. Meldrum the attempt was made to study the alkali metals dissolved in melted lead in the same manner as the amalgams above mentioned. Many difficulties were met in this research, the chief being due to the formation of alkali subchlorides. All other difficulties in the technique were successfully overcome, but this obstacle, inherent in the nature of the problem, still remained. Nevertheless, approximate results which may be of value were obtained from mixtures in which equilibrium had been nearly, if not quite, attained. Incidentally a series of exact measurements of the

melting-points of binary and ternary mixtures of all the five alkali chlorides were obtained with a degree of precision which left nothing to be desired. The relation between the eutectic points of these mixtures is especially interesting.

A number of papers concerning previous investigations were published during the year; their titles will be found in the Bibliography, p. 53.

Sherman, H. C., Columbia University, New York, N. Y. Grant No. 850, allotted Dec. 13, 1912. *Continuation of the chemical investigation of the amylases.* (For previous report see Year Book No. 11.) $1,200

During the year this investigation has been continued according to the general plan outlined in the report for 1912, special attention being given to the purification of malt amylase and the study of the chemical nature of the amylase preparations from malt and from the pancreas. Preparations of much higher enzymic activity than had been reported by previous investigators have been obtained and such preparations both from malt and from pancreas have been clearly shown to be of protein nature, yielding the typical forms of amino acid nitrogen on hydrolysis. The chief features of the work of the year may be briefly described as follows:

Much time has been devoted to the purification of malt amylase with a view to the development of a method capable of yielding a uniform product of maximum activity corresponding to the pancreatic amylase previously described. By procedures varied in detail, but in principle based partly upon Osborne's method for malt and partly upon our method for pancreatic amylase, 38 experiments in purification have been made, of which 34 have yielded products of greater activity than previously described for malt amylase; 7 of these have shown from three to four times the diastatic power of the most active preparation reported by previous investigators; 29 other purification experiments made by essentially different methods have yielded much less active products. Since the best preparations thus far obtained from malt are less uniform in activity than those obtained from the pancreas, the study of methods of purification is being continued.

The active amylase preparations obtained from malt correspond in general properties with Osborne's description of malt diastase published in 1895–96 rather than with the descriptions of some of the more recent investigators. The material is a yellowish-white solid approaching the typical proteins in nitrogen content and showing typical protein color-reactions and the appearance of a colloid under the ultramicroscope. When heated in water solution it coagulates; the coagulum gives a violet-blue, and the filtrate a rose-red, biuret reaction. Since this material, like the pancreatic amylase,

appears to be of protein character, the small amounts of substance thus far obtained have been utilized chiefly for study of the forms of nitrogen present.

The eight forms of nitrogen distinguishable by the methods recently developed by Van Slyke—namely, the nitrogen in the forms of arginine, of histidine, of lysine, of cystine, the amino and non-amino nitrogen of the hydrolytic products not precipitable by phosphotungstic acid, the melanin nitrogen, and the nitrogen liberated as ammonia on direct acid hydrolysis—have been determined in the preparations of highest activity thus far obtained from malt, in preparations of lower activity, and in the protein material more readily precipitable by alcohol which had little diastatic power. The same determinations have been made upon amylase preparations of maximum activity and of lower activity from the pancreas. Each of these five products shows all the eight forms of nitrogen in proportions well within the range exhibited by typical protein substances. These results make much more definite our conception of the chemical nature of these enzyme preparations and may be expected to throw important light upon the origin of enzymes and their chemical relations to antecedent substances.

In connection with this work upon the purification of the amylases and the study of their chemical nature, numerous observations upon the changes in activity which the enzymes undergo in different solvents and determinations of the quantitative relations of the amyloclastic and saccharogenic activities have been obtained, and a basis for the reinterpretation of such data has been secured which may greatly facilitate the clearing up of certain apparently anomalous results obtained in earlier investigations.

A considerable amount of work has also been accomplished upon the influence of different electrolytes and the more precise determination of the optimum conditions for the diastatic action of the amylases. This work is being continued and arrangements are being made to supplement these determinations by further direct observations of the behavior of the enzymes under the ultramicroscope.

Three papers dealing respectively with the experiments upon the purification of malt amylase, the comparison of amyloclastic and saccharogenic powers, and the forms of nitrogen in amylase preparations from the pancreas and from malt have been prepared for publication.

The writer takes pleasure in acknowledging his indebtedness to several collaborators. Miss M. D. Schlesinger has continued to give her entire time to these investigations and at different times during the year Professor H. T. Beans, Dr. A. O. Gettler, Mr. P. W. Punnett, Dr. A. R. Rose, and Mr. A. W. Thomas have coöperated in certain parts of the work.

EMBRYOLOGICAL RESEARCH.

Mall, Franklin P., Johns Hopkins University, Baltimore, Md. Grant No. 874, allotted Feb. 20, 1913. *Embryological research.* $15,000

The grant for embryological research was made available upon March 21, 1913, and steps were taken at once to inaugurate the work. I was then appointed Research Associate; Miss Rebecca D. Hepburn, private secretary; Dr. Herbert M. Evans, Research Associate, on June 1; Mr. James F. Didusch, artist, on September 1; and Miss Charlotte W. Wilson, technical assistant, on September 15.

Work was begun at once to make a catalogue of my collection of human embryos. The many histories, notes, drawings, photographs, specimens, and serial sections are now being recorded uniformly in books which have been printed for this purpose. The catalogue should be completed during the calendar year. The more valuable specimens and all of the records are now being filed after a system in fire-proof safes especially constructed to receive them.

A vigorous campaign has been carried on for new specimens of human embryos, through correspondence and through the distribution of circulars and reports. These notices have reached more than half of the physicians of the United States. At the suggestion of the late Dr. Billings, many letters have been sent to the Orient, and the first replies received indicate that they will bring interesting and valuable information. The result of these efforts has been most satisfactory. Within six months about 150 specimens, mostly young ones, have been added to the collection, many of which are of great value and some are unique. Formerly it took three to five years to collect this number of embryos. The histories which accompany these specimens are much better than the older ones, special pains having been taken to secure them.

The work is being carried on in a number of rooms in the Anatomical Laboratory of the Johns Hopkins University, and its facilities for embryological investigation, which are unusually good, are also being used. Three fire-proof rooms in the new Phipps Psychiatric Clinic have been generously placed at our disposal by Dr. Adolf Meyer, director of the clinic, and Superintendent Smith, of the Johns Hopkins Hospital. In these rooms the better part of the collection is now safely housed.

During the spring a number of human embryos, mostly in serial sections, have been loaned for study to Professor Edward Fawcett, of Bristol, England; Professor J. M. Flint, of Yale; Professor Thomas S. Cullen, of the Johns Hopkins Hospital; Dr. J. L. Bremer, of Harvard; Professor George B. Jenkins, of Louisville, and Dr. Ernest Cullen, of Detroit. Aid has also been rendered in completing or in preparing for press the following investigations: A monograph by Dr. Lewis H.

Weed on the nuclear masses in the lower part of the human medulla, which will be published by the Carnegie Institution of Washington; a critical review of recent work on the development of the lymphatic system, by Professor Florence R. Sabin, to be published in the Ergebnisse fur Anat. u. Entwickl.; a chapter on the development of the ventral abdominal wall in a book on the umbilicus by Professor T. S. Cullen, to appear shortly; an article by Dr. Ernest K. Cullen and myself on an ovarian pregnancy located in a Graafian follicle, in Surgery, Gynecology and Obstetrics; and an article on the development of the structural unit of the pancreas by Dr. George W. Corner, for the American Journal of Anatomy.

During the spring and summer research in human embryology was pushed with increased vigor. A study of tubal pregnancy, which includes nearly 100 specimens, is drawing to a close. An effort has also been made to establish the norm for the external form of human embryos less than 25 mm. long. At present it is possible to recognize 14 distinct stages in embryos less than an inch long, and this provisional classification will be perfected as more specimens are recorded either here or elsewhere. At the same time uninterrupted work has been given to the study of the anatomy of the human embryo. This work, hitherto in a fragmentary state, and depending on the chance activities of various investigators, can now be pursued in a systematic way. A laboratory of human embryology should be peculiarly fitted to do this. Such an effort, free from the fortuitous character of experiment, may constitute an important part of the routine activity of the department. In addition to the development of specific tissues or organs, monographs should be issued on the structure of the embryo at representative stages. The Institution has already made it possible to complete the work of Professor Lewis on the development of the head with special reference to the muscular system, which has occupied him for a number of years. Studies of young embryos are represented by the records and reconstructions which Professor Evans has been assembling on the anatomy of human embryos between 2 mm. and 4 mm. in length. A satisfactory presentation of the complex anatomy of older stages has also been begun in the detailed study of an unusually well-preserved injected embryo 21 mm. long (No. 460 of the collection). Sections of the embryo are being photographed at 50 diameters with microplanar lens, drawings having already been secured of the surface form.

A colony of guinea-pigs has been secured for breeding purposes, and compartment cages built so that individual records will be possible. At present experiments are being made on the behavior of the placenta toward vital stains, but valuable embryological material will also be obtained from the colony.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. Grant No. 851, allotted December 13, 1912. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–11.) $4,000

The collection and study of the climatic data of the geologic record in hand at the time of the last report were continued during the early part of the year. As the assembling data took form, it became increasingly apparent that the earlier geologic climates, like the later, were intimately related to the distribution of land and water, and hence that any true basal conception of the earth's climatology must embrace the agencies that gave form to the earth's primitive configuration. While the influence of physiographic features was thus clear, it was evident also that there must have been an overmastering planetary circulation of the atmosphere that persisted through all influences arising from surface features and was a potent force in the early climatology. It seemed advisable, therefore, to reconsider the relations of surface features to the planetary circulation in the earliest stages of the earth's atmospheric history and to form some estimate, if possible, of the extent to which the one might have influenced the other in the genetic stages. There was a special reason for doing this under the planetesimal conception of the growth of the earth or any analogous form of accretion, for it is evident, upon consideration, that if the body of the earth grew to maturity by reason of the accession of small bodies plunging into its atmosphere in meteoric fashion, a notable portion of their substance must have been dissipated as dust in the upper air and have found its final resting-place under the conditions imposed by the atmospheric circulation. The distributing and precipitating functions of the atmosphere must thus have effectively influenced the lodgment of the accessory matter and hence the proportionate growth of the several parts of the earth's surface. The conditions of the case seem to make it clear that the proportion of the planetesimal matter dissipated to dust by its plunge into the air would be sufficiently large to form an appreciable factor in the total growth, and that any areal differentiation in the lodgment of this portion due to atmospheric conditions would affect the growth-form of the earth as distinguished from the diastrophic form imposed by internal forces. The growth-form would, further, be in itself a factor in determining the phases of diastrophic action that might run parallel with growth or come into action after growth ceased. It thus came to appear that, under the planetesimal conception, atmospheric action was an inevitable factor in determining the surface configurations and that these in turn influenced the subsequent atmospheric action.

This cyclic action raised the radical question whether atmospheric circulation and precipitation were not fundamentally concerned in giving shape to the primitive continents and oceanic basins, which later in turn seemed to so much influence climate, a cyclic relation of cause and effect. The middle portion of the year was given to studies along this line. These led to the conviction that the primitive conformation of the earth's exterior was the joint product of (1) diastrophic agencies that acted on the earth nucleus and on its successive accretions as they were added, modifying the spheroidal form determined by rotation and gravity; (2) atmospheric agencies that determined the localization of the planetesimal dust that settled slowly through it; and (3) hydrospheric action whose localization was largely predetermined by the previous action of the diastrophic and atmospheric agencies, both of which were more primitive in time and more fundamental in nature. These studies seemed to throw new light on the forms and meanings of the great features of the earth's surface.

The agencies that necessarily come into a study of this kind are so complex and obscure in their interactions on one another and in their cyclical reactions on themselves that conclusions are inevitably tentative and may well be held in reserve for working trial by the naturalistic method while more concrete studies are pursued, to which, however, they furnish suggestive stimulus and a measurably new basis.

The work recently in hand has been the revision and organization of climatic data previously collected for a paper on the climates of the Paleozoic era, and soon to be offered for publication.

HISTORY.

Osgood, Herbert L., Columbia University, New York, N. Y. Grant No. 853, allotted December 13, 1912. *Completion of an institutional history of the American colonies during the period of the French wars.* (For previous report see Year Book No. 11.) $1,200

During the past year work on my history of the American colonies during the eighteenth century has been steadily progressing. I have published nothing on the period, for the reason that I am treating it as a whole and nothing will be ready for publication until practically the entire work is finished. I have written during the past year about twenty chapters on the period between 1690 and 1715. Many of these are nearly in completed shape, others are less perfect.

Dr. Mereness has been doing satisfactory work during the year, most of the time in New York on printed material which I had not used. Since April he has taken notes at Albany on a large part of the minutes of the Executive Council of New York and at Hart-

ford on the manuscript records of Connecticut during the eighteenth century.

Because of the dispersion of the material, the large proportion of which is in manuscript, and because of the lack of satisfactory earlier treatises on the period as a whole, the work necessarily progresses slowly.

Bandelier, Adolf F., New York, N. Y. Grant No. 751, allotted December 14, 1911. *Completion of a documentary history of the Rio Grande Pueblo Indians of New Mexico.* (For previous report see Year Book No. 11.) $2,000

Since my last report I have continued my studies in public and private archives in Mexico, gathering all that was accessible and examining critically all documents related to my task. I have, in the meantime, also paved the way for work in Spain by establishing connections with persons who will assist us in every possible way.

CLASSICS OF INTERNATIONAL LAW.

Scott, James Brown, General Editor, Washington, District of Columbia. Grant No. 712, allotted December 13, 1910. *Preparation and publication of the Classics of International Law.* (For previous reports see Year Books Nos. 9–11.) $10,000

The project for the republication of the Classics of International Law was submitted to the Carnegie Institution of Washington in my letter of November 2, 1906, and shortly afterwards I was authorized to take supervision of the work as general editor. Two of the works specified in the original proposal have already been published, namely: the text of Zouche entitled "Juris et Judicii Fecialis, sive, Juris inter Gentes et Quaestionum de Eodem Explicatio," edited by Dr. Thomas Erskine Holland, the translation of which was made by Mr. J. L. Brierly. This work appeared in 1912. The very important treatise of Ayala entitled "De Jure et Officiis Bellicis et Disciplina Militari" was edited by the late Professor John Westlake, the translation was made by Mr. John Pawley Bate, and the two volumes were published in the course of the present year.

The text of Grotius entitled "De Jure Belli ac Pacis" has been photographed from the edition of 1646, and the volume has been issued. The translation has been made by Dr. John D. Maguire, professor of Latin in the Catholic University of America, and will doubtless appear in the year 1914.

Vattel's "Droit des Gens," first published in 1758, has been reproduced photographically, and the English translation has been made by Dr. Charles G. Fenwick. It is highly probable that the work will be issued as a whole in the course of 1914.

The tractate by the Italian jurist, Legnano, entitled "De Bello, de Represaliis, et de Duello," written in 1360, but first published in 1477,

is in press. Professor Holland, who edits the treatise, obtained the original manuscript from the University of Bologna and it has been photographed by the Clarendon Press of the University of Oxford. Professor Holland has prepared a revised Latin text to accompany the manuscript, and has secured the services of Mr. J. L. Brierly as translator of the text. The new edition of Legnano, with the original manuscript for the first time made accessible to scholars, will, it is confidently expected, likewise appear in the course of 1914.

Rachel and Textor are considered as having laid the foundation of the so-called positive school of international law, the school which rejects the alleged law of nature and relies upon the practice of nations as the basis of international law. The work of Rachel, entitled "De Jure Naturæ et Gentium," appeared in 1676; the treatise of Textor, entitled "Synopsis Juris Gentium," in 1680. I had secured as editor the services of Professor Ludwig von Bar, whose recent death the publicists of all countries deplore, and his introductions to these two works were already in type prior to his death. Mr. John Pawley Bate, who made the admirable translation of Ayala, has rendered the same service for Rachel and Textor, and it is hoped that one or both of these works will be published in the course of 1914.

The tractates of Victoria, entitled respectively "De Indis" and "De Jure Belli," published in his "Relectiones Theologicæ" in the year 1558, will be edited by the distinguished Belgian publicist, Professor Ernest Nys, who will supply a comprehensive introduction to the works of this author, who is justly considered not merely as an illustrious publicist, but as one of the founders of international law; the translation will be made by Mr. John Pawley Bate.

It is thus seen that the Classics of International Law are no longer a mere project, and it is hoped that editions of the works selected for republication will appear at regular intervals, as arrangements for their publication are made.

That the editions of Zouche and Ayala have been well received appears from the following extracts from reviews translated from the Revue générale de droit international public:

If we are to judge by the first volume of the collection, which has just appeared and which is devoted to the "Juris et Judicii Fecialis" of Zouche (1590–1660), Mr. Scott has triumphed over all difficulties. The volume is indeed a most noteworthy one, both in form and in content. The original text, reproduced photographically, brings the book itself back to life, and the English translation by Mr. J. L. Brierly is worthy of the author whose work it makes known. Mr. Scott's idea is to have the text of the works published in the "Classics of International Law," which include, in addition to Grotius, his chief precursors and his most renowned successors, preceded by an historical, biographical, and bibliographical introduction, written by a specialist in the law of nations. The "Juris et Judicii Fecialis" was intrusted to Mr. T. E. Holland as editor. There could have been no hap-

pier choice. The world-wide reputation which the eminent British publicist has acquired, both by his courses on international law at Oxford, where he has long been professor, and the many books which he has published, was a sure guarantee that the introduction to the work of Zouche would be perfect. * * * There is a fine portrait of the author as frontispiece to this work. It is to be hoped that this collection, published under the supervision of Mr. Scott, will continue to be enriched with editions as well executed as this, and that they will not be long in appearing. The publication of this series is a landmark in the history of international law. The learned American publicist deserves the thanks of the scientific world for undertaking this work. (Vol. XIX, 1912, pp. 419–420.)

After the treatise of Zouche, the "Juris et Judicii Fecialis," edited by Mr. Holland, there has now appeared the work of Balthazar Ayala, "De Jure et Officiis Bellicis et Disciplina Militari," by Mr. Westlake. This new work is in every respect a worthy successor to the first. The introduction written by Mr. Westlake gives, with the customary conciseness of the learned professor, complete biographical information concerning Balthazar Ayala and an accurate commentary upon the different chapters of the treatise which is reproduced. It sets out in perfect relief the ideas which it contains and shows the influence which they had upon the development of international law. The activity with which the publication of the Classics is proceeding does great honor to Mr. Scott. The works he has selected for publication and the jurists he has chosen to edit them also entitle him to the gratitude of all who are interested in the law of nations. (Vol. XX, 1913, p. 546.)

LITERATURE.

Bergen, Henry, Brooklyn, New York. Grant No. 833, allotted December 13, 1912. *Completion of the preparation for publication of the text of Lydgate's Falls of Princes.* (For previous report see Year Book No. 11.) $1,800

Dr. Bergen has been engaged in preparing the text of Lydgate's "Falls of Princes" for the press, *i. e.* He has copied the Oxford MS. Bodley 263, as the basis of the text, and collated it with the British Museum MSS. Royal 18 D. IV. and Harley 1245. The progress of the work has been satisfactory.

Sommer, H. Oskar, Astolat, Camberley, Surrey, England. Grant No. 817, allotted June 12, 1912. *Completion for publication of researches on Arthurian Romances.* (For previous reports see Year Books Nos. 5–11.) $2,000

Doctor Sommer's work for the Institution, in the publication of his researches on the Arthurian Romances, was substantially completed during the year by the issuance of volumes VI and VII of the series. On account of serious ill-health he did not complete the index raisonné, but may furnish it for publication at a later date, when his health is restored.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. Grant No. 834, allotted December 13, 1912. *Application of Cremona groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9–11.) $1,200

The theory of restricted systems of equations when applied to a particular problem failed to yield a result. Professor Coble accordingly undertook a revision of the theory. The attempt was made to handle the various phases in their greatest generality. The results are given in a forthcoming paper.

The first question set was: Given an M_v in S_n, n spreads containing M_v meet in how many points outside M_v? This was solved by the use of $v+1$ "index-numbers" attached to M_v. These index-numbers were determined in special cases. A more general problem is: Given an M_{v-k} on an M_v in S_n, v spreads on M_{v-k} meet M_v in how many points outside M_{v-k}? This was solved by the introduction of the $v-k+1$, "relative index-numbers" of M_{v-k} as to M_v.

A spread of v dimension composed of an M_v and M_s, $s \leqq v$, has for index-numbers the sums of the index-numbers of M_v and M_s, *provided* M_v *and* M_s *have no common point.* The necessary modification when M_v and M_s have in common an M_1 was discovered. Again, in S_n spreads M_{n-v_i}, where $v_1+v_2+ \cdots =n$, all contain M_v; in how many points outside M_v do they meet?

The above are specimens of the questions which have been set. Not all have been completely answered, but enough has been done to give hope of completely general results.

Another class of problems under way, which is central in the theory of rational curves and equally so in that of rational surfaces, is the following: Given a system of forms, calculate all their linear combinants, determine the relations which these linear forms satisfy, and select those which define them as combinants of the original forms.

MATHEMATICAL PHYSICS.

Moulton, F. R., University of Chicago, Chicago, Illinois. Grant No. 852, allotted December 13, 1912. *Investigations in cosmogony and celestial mechanics.* (For previous reports see Year Books Nos. 4, 5, 8–11.) $2,000

The following work has been completed during the last year and has been accepted for publication:

(1) *On the solution of linear equations having small determinants:*

This paper treats of linear equations whose coefficients and right members are given by experiments or observations to a limited number of places. The degree of precision of the solutions is determined. It is proved that when the determinant of the coefficients is small, the solution is determined to a smaller number of places than are given in the coefficients; the precise extent of the uncertainty is

found; the situation is given a geometrical interpretation; and it is shown how to reduce the number of places used in the calculations, without impairing the accuracy, to the number of places to which the final results are determinate. The question, which has important astronomical applications, is illustrated by a numerical example.

(2) *A direct and general method of determining orbits:*

The contribution to this much-worked problem is both theoretical and practical. Among the theoretical features are: (*a*) a direct application of the geometrical and dynamical conditions, carried out so that no artificial difficulties are introduced; (*b*) an investigation of the degree of indetermination of the solution; (*c*) a complete discussion of the exceptional cases which may arise; (*d*) proof that the apparent motion of the observed body can not be permanently in a great circle unless it moves along the ecliptic; (*e*) a general analytic solution of the problem which avoids all successive approximations. The greatest practical contribution is that almost at the very beginning, after the indetermination in the final results has been found, the number of places used in the computations may be correspondingly reduced. In most cases which arise in practice in preliminary orbit computation five-place tables are sufficient.

(3) *The introduction to celestial mechanics:*

This has been completely revised and is in the hands of the printers.

(4) *The Lagrangian solutions of the problem of bodies:*

The Lagrangian solutions of the problem of three bodies are those in which the ratios of the mutual distances of the bodies are constants. The methods of Lagrange apply only to three bodies. It is shown how to find the number of solutions when there are any number of bodies. The method of treatment depends on the theorem that no solutions can appear or disappear as the masses of the bodies vary.

(5) *On the fission of stars:*

The difficulties of the theory that binary stars originate by fission of single stars are brought out by a discussion of the conditions for equilibrium of a mass whose rotation increases only as a consequence of its contraction.

METEOROLOGY.

Bjerknes, V., University of Leipzig, Leipzig, Germany. Grant No. 835, allotted December 13, 1912. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–11.) $1,800

During the past year a German edition has appeared of the first and second volumes "Statics" and "Kinematics" of the author's book "Dynamic Meteorology and Hydrography."

The proposition of the author referred to in the previous report, concerning the introduction of the C.G.S. units of pressure, bar, decibar, centibar, millibar, instead of the millimeters or the inches of mercury, was accepted by the International Meteorological Committee at its meeting at Rome, 1913, in the form that it is recommended to use the old and the new units side by side in aerological publications.

On January 1, 1913, the author was appointed professor of geophysics at the University of Leipzig and director of the new Geophysical Institute of this University. This Institute aims to bring into practical use for investigations in dynamical meteorology the methods worked out in the "Dynamic Meteorology and Hydrography." For this purpose the Institute has started the issue of a publication, "Veröffentlichungen des Geophysikalischen Instituts der Universitat Leipzig," in which the results of the international meteorological ascents are worked out synoptically according to the mentioned methods.

The preparatory work for the third volume, "Dynamics," of the "Dynamic Meteorology and Hydrography" has been continued. The assistants, Mr. Hesselberg and Mr. Sverdrup, have been occupied principally with an extensive investigation concerning the influence of friction upon atmospheric motion.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. Grant No. 831, allotted December 13, 1912. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–11.) $15,000

The report of work done under this grant covers the period from April 1, 1912, to March 31, 1913. During this time the experiments in progress at the end of the previous year were continued and the results of the investigations, so far as completed, have been published in various journals (cf. Bibliography, pp. 52, 53).

The experiments with zein, the principal protein constituent of maize, have been extended to an elaborate study of the nutritive value of the proteins of this seed for both growth and maintenance. These experiments are now practically completed, and the results, which will soon be published, can be summarized as follows:

The long-recognized nutritive inefficiency of maize, as the sole food of domestic animals, has been found to be caused largely, if not wholly, by deficiencies in the constitution of its proteins. We have previously shown that when zein, which yields no tryptophane or lysine, is the only protein in the diet of either a young or a mature animal, a decline in body-weight at once begins and death ultimately results; and that if a quantity of tryptophane, equivalent to 3 per

cent of the zein, is added to the diet, mature animals are maintained for a long time. We have now found that young animals can be maintained for long periods by this diet, but that they fail to grow; and further, that if a similar quantity of lysine is also added to the food, they can grow for a considerable time at a nearly normal rate. If a part of the zein of the food is replaced by another protein capable of promoting normal growth, young animals grow as rapidly, and for as long a time, as if the entire protein of the diet consisted of one adequate for growth. Different proportions of each of the several proteins tested are required to render zein effective for satisfactory growth. A mixture of one part of lactalbumin and four parts of zein promotes growth at a normal rate, but a mixture of equal parts of casein and zein, or one part of zein and three of edestin, is required to produce the same result.

Differences in the proportions of the amino-acids contained in the molecules of these proteins may account for the widely different quantities of each of them required to supplement the deficiencies of zein. Thus edestin yields a relatively small proportion of lysine, which is wholly absent from zein. On a diet containing equal parts of zein and edestin very little growth is made, but if tryptophane and lysine are each added, in a proportion equal to 3 per cent of the zein, normal growth ensues. It is possible that the superior efficiency of lactalbumin in supplementing zein is due to a high content of both lysine and tryptophane.

Young rats fed on diets containing either zein or phaseolin, as the sole protein of the diet, decline rapidly in weight, but when given a food containing equal parts of these two proteins they are maintained, but do not grow. These experiments are of interest in connection with the feeding of corn, for they indicate that this important cereal can be utilized most profitably when fed in combination with other foods containing proteins which, by their chemical constitution, best supplement the deficiencies of zein.

In this connection experiments have been made with a preparation of "corn gluten," which is a by-product of the manufacture of starch and is largely used as a concentrated feed for domestic animals. This product contains about 31 per cent of zein, 14 per cent of protein insoluble in alcohol, but soluble in dilute alkali, 5 per cent of ether-soluble matter, and about 50 per cent of insoluble carbohydrates, of which a part is starch. Foods were made with this corn gluten in such proportions as to imitate as nearly as possible the proximate composition of our standard "protein-free milk" diets. These contained 18 per cent of the corn protein, a quantity of the carbohydrate of the standard food being substituted by the carbohydrate supplied by the corn gluten. On this diet rats have been well maintained for long periods, but with very little growth. Replacing a part of the

corn gluten protein with lactalbumin, casein, or edestin gave results very similar to those obtained by corresponding additions of these proteins to pure zein diets. The proportion of lactalbumin required to promote normal growth was as small as in the zein experiments, and the superiority of casein over edestin was likewise manifest. These results are in harmony with practical experience in feeding, for a combination of corn meal and milk has long been esteemed as a food for young animals.

The outcome of these experiments has an important experimental bearing; for foods made with corn gluten have proved unusually effective in maintaining animals at nearly constant weight and in good condition over long periods. By means of this food it will be possible to obtain a large number of stunted animals, for studying the histological changes that occur when growth is suppressed by a diet containing an inadequate protein, as well as for learning the influence of delayed growth on the retention of the capacity to grow and the length of life of animals thus stunted. Furthermore, since large quantities of this corn gluten can be obtained at small cost, similar experiments can now be tried on other species of animals larger than rats.

The experiments with zein foods to which tryptophane and lysine are added shed new light on the relations of the individual amino-acids to nutrition. While proteins yielding tryptophane are essential for the maintenance of either mature or young animals, those containing lysine also are required for growth. This conclusion is further supported by the fact that, whereas a mature animal can be indefinitely maintained, and even produce young, on a food containing gliadin as its sole protein, a young animal can not grow thereon, unless lysine—in our experiments equivalent to 3 per cent of the protein—is added to the food. These observations appear to be the best evidence yet recorded that the amino-acid complexes are the units with which young animals deal in the construction of new tissue.

The practical importance of a recognition of this fact is well illustrated by the recent experiments of Dr. Sweet and his associates, who have succeeded in controlling the growth of tumors, transplanted into mice, by feeding them on one of the diets (described in an earlier paper by us) which was incapable of promoting the growth of young rats.

During the past year a series of young rats has been carried at nearly constant weight for the purpose of learning how long animals thus stunted can be kept in good physical condition, what is the best way to accomplish this, how long such animals retain the capacity to grow, and what effect suppression of early growth may have on their subsequent development and length of life. These experiments, which have now been in progress for nearly a year, have been so successful that up to the present time only three of these animals have

died. The remaining animals, which are now about 300 days old, are still in good physical condition, although many of them weigh little more than one-third as much as do normally fed animals of the same age. The plan followed was to first feed the rat with a food incapable of promoting growth until it declined about 10 grams in weight and then to give it our "milk-powder food" for a day or two until it had regained its lost weight. This procedure has made it necessary to weigh the rats daily, so that the foods could be changed at the proper time.

Two female rats, which had failed to grow above 170 grams during the progress of experiments carried on in the previous year, were kept at constant weight by the above-described method, until one was 480 and the other 554 days old. On a normal mixed diet the younger one has subsequently gained 37 per cent, reaching a weight of 220 grams—somewhat more than the average maximum of female rats which have grown normally on mixed diets. The older rat has, at the time of writing, gained 18 per cent, and is still gaining, although at the time this deferred growth began it had reached about twice the age at which rats normally cease to grow.

These experiments indicate that animals which have failed to grow in consequence of defective diets do not early lose the capacity to grow to their full normal size. We shall soon be able to control these observations by testing other animals which have been permitted to make much less growth than the two just described.

In our last report we stated that when rats are fed on our "protein-free milk" diets, containing an adequate protein, they grow normally until they reach about three-quarters of their natural size. After this they soon decline and die, unless supplied with the "milk food" or with a normal mixed diet. This failure is a direct result of growth, for rats fed on the "protein-free milk" foods which contain an inadequate protein, such as gliadin, live very much longer. We thus have the curious fact that rats which grow die, while those that do not grow live. A very large number of experiments have been carried on during the past year for the purpose of discovering the cause of the failure of the rats to complete their normal growth on the "protein-free milk" foods. Control experiments with many rats fed on the "milk food" have shown that this contains everything essential for growth. Not only do such rats grow rapidly to full size, but they produce large litters of young, which in turn grow normally and are fertile when fed exclusively on the same "milk food." It is thus evident that the milk food contains something essential for perfect growth which is lacking in the "protein-free milk" food.

As it seemed fair to presume that the "protein-free milk" contains all of the constituents of the milk except the protein, fat, and suspended solid matters (cell débris, bacteria, etc. ?), we attempted to

determine the possible influence of these substances on growth. Since our previous experience made it very improbable that the removal of the protein was the cause of the failure to continue to grow, we tried the effect of diets in which a part of the lard of the "protein-free milk" food was replaced by a quantity of butter equal to that contained in the milk food. The outcome of a large number of experiments, in which this "butter food" was given to rats declining after earlier growth on "protein-free milk," was exactly the same as when the milk food was supplied.

The fact that rats can make good growth over comparatively long periods on diets free from fat makes it improbable that the glycerides of the fatty acids, of which butter is chiefly composed, cause the resumption of growth. As it was possible that the small amount of cellular matter contained in the suspended solids of the butter might have caused the renewed growth, a series of experiments was made with pure butter fat, obtained by centrifugating butter which had been melted at 45°. This perfectly clear fat was quite as effective as the butter in promoting resumption and continuation of growth. It is evident that the butter-fat fraction of milk contains something essential for long-continued, normal growth; but we are not yet in a position to suggest what this substance may be.

A continuation of our experiments with "artificial protein-free milk" indicates that the success of our first series of experiments was probably due to minute amounts of impurities contained in the chemicals used in making the preparations of this material fed at that time. New preparations made with carefully purified chemicals failed to promote growth in any degree comparable with that obtained in the first series of experiments. We were therefore led to try adding minute quantities of iodine, fluorine, manganese, and aluminum, all of which have been found in traces in the tissues of various species of animals. The results thus far obtained with this preparation of "artificial protein-free milk" have been decidedly superior to those obtained without the addition of traces of these inorganic elements, but we are not at present prepared to draw final conclusions in respect to the inorganic constituents of the diet essential for the growth of the rat.

Whether or not, in addition to inorganic substances, some organic constituent of the natural "protein-free milk" has an important influence on growth has received our attention, and much time has been spent in attempting to extract such a substance from the "protein-free milk." The effect of such extracts has been studied, but the experiments now in progress do not yet justify final conclusions.

The progress of our work during the summer of 1912 was greatly impeded by the development of intestinal disturbances in a large proportion of our young experimental rats, in consequence of which

they failed to grow on diets which previous experience had shown to be adequate for growth. An examination of our records showed that a similar condition prevailed during the two preceding summers; but as we then had only a few young rats under observation our attention was not especially attracted thereto. The same trouble has also developed this summer. This condition is attended with diarrhea and afflicts the rats on the natural as well as those on the artificial "protein-free milk" foods. In order to determine whether or not this intestinal disturbance was of bacterial origin, we have secured the cooperation of Professor L. F. Rettger, of Yale University, who has made a study of the intestinal flora of the rats in health, when afflicted with this disease, and under a great variety of conditions of feeding. Although Professor Rettger has not yet detected a definite cause for the disease in question, he has obtained many interesting data respecting the influence of our experimental diets on the intestinal flora of the rat. He expects to be able to make a report on the results of this work at an early date.

Last year Dr. Ruth Wheeler undertook to repeat some of our earlier experiences on the maintenance and growth of rats by feeding another species—albino mice—in comparable ways. A brief review of her findings is published (see Bibliography, p. 54). In many respects they confirm our conclusions from the experiments with rats. Mice were kept for very long periods (up to 6 months) on diets of isolated food-stuffs containing a single protein. The comparative adequacy or inadequacy of different proteins for maintenance, which we observed with rats, was likewise found to be true in general for these smaller animals. Stunting experiments were also conducted with them; and it was found that the capacity to grow was still retained long after the age at which the growth of mice normally ceases. In respect to the dietary conditions appropriate for growth, however, the trials on mice indicated that the suitable proportions of the nutrients—particularly of protein and inorganic salts—may be quite different in the smaller species from what pertains in larger ones. The experience gained from this work with the mice convinced us, further, that our earlier selection of the rat as an experimental animal was well advised.

Besides the work here reported an extensive series of anaphylaxis experiments have been conducted in cooperation with Professor H. G. Wells, of the University of Chicago, the results of which have just been published (*cf.* Bibliography, p. 54). This study has shown that a common anaphylaxis reaction can be developed by two chemically distinct but similar proteins of different biological origin, thus indicating that the specificity of this reaction is determined by the chemical constitution of the protein rather than by its biological origin. This is in harmony with the fact that chemically closely related pro-

teins have, as yet, been found only in tissues that are biologically nearly related. Thus guinea-pigs sensitized with gliadin from wheat, or from rye, give strong anaphylactic reactions with hordein from barley, but these are not as strong as the reactions obtained with the homologous protein. Similar results are obtained if the sensitizing protein is hordein and the protein used for the second injection is gliadin. These results are of interest because gliadin and hordein, while similar in their chemical constitution, are nevertheless distinctly different proteins. Saturation experiments showed that guinea-pigs when sensitized with either gliadin or hordein, and then saturated with the heterologous protein, still react strongly when injected with the homologous protein. Gliadin and glutenin react anaphylactically with one another, although they are proteins of distinctly different types. The conclusion appears justified that these chemically different proteins contain common reactive groups. Guinea-pigs sensitized with glutenin do not react anaphylactically with hordein, thus showing that the reaction between gliadin and glutenin is not caused by an incomplete separation of these latter proteins, but by reactive groups common to gliadin and glutenin, but absent from hordein. These experiments demonstrate that the "group reactions" characteristic of biological reactions between closely related species, which usually have been interpreted as indicating the presence in related organisms of identical as well as distinct proteins, can really be exhibited by single isolated proteins from related organisms. In other words, biological relationship and chemical relationship seem to be much the same.

PALEONTOLOGY.

Case, E. C. University of Michigan, Ann Arbor, Michigan. Grant No. 836, allotted December 13, 1912. *Completion of the work on the Permian vertebrate fauna of North America.* (For previous reports see Year Books Nos. 2, 4, 8–11.) $2,000

Mr. Case has continued work upon the Permo-Carboniferous fauna of North America during the year. Especial attention has been paid to the geographical distribution of the fauna, its origin, evolution, and extinction—its relation to foreign forms and its migrations. The location of the various beds in which the fauna has been found has been studied and an attempt made to determine the area and position of the deposits in Permo-Carboniferous time and the age of the beds. Considerable work has been done upon the structure and the material of the beds in an attempt to determine the climatic and other factors which governed the evolution of the fauna. During the summer of 1913 Mr. Case extended his field work into Arizona and revisited the Texas localities.

The report in preparation will contain detailed maps of the known Permo-Carboniferous localities and paleogeographic maps of the time restorations of the various animals, and a full discussion of their life histories and environment.

As a part of the work done under this grant Dr. Case has prepared, in collaboration with Professor Williston, of the University of Chicago, and Dr. Mehl, of the University of Wisconsin, a report on the Permo-Carboniferous Vertebrates of New Mexico, which has appeared as Publication 181 of the Carnegie Institution of Washington.

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia. Grant No. 837, allotted December 13, 1912. *Investigation of the vertebrate paleontology of the Pleistocene epoch.* (For previous report see Year Book No. 11.) $3,000

During the year which has elapsed, most of my time has been passed in studying the Pleistocene vertebrate material in the U. S. National Museum. As before, I have also been engaged in collecting data regarding finds of Pleistocene vertebrates, mapping them and studying their relationships to the various recognized glacial drift sheets. From some of the localities have been received extremely valuable skulls and other remains.

During the latter part of 1912 I was engaged in the study of the fossil horses of our country. From the United States I described four new species, two of them based on nearly complete skulls; from Alaska was described a new subspecies whose type is a large part of a skull. Two new ruminants were described from the Pleistocene of Iowa. The early part of the present year was devoted to a study of the fossil bisons of North America. Following this I examined some of the Pleistocene camels. Papers on both these groups are in press.

A paper of about 250 pages has been published on the Pleistocene vertebrates of Indiana. This region furnishes an important late Pleistocene fauna. Some attention has been given to the fossil mammals of Iowa, where an early Pleistocene fauna has come to light.

Wieland, G. R., Yale University, New Haven, Connecticut. Grant No. 838, allotted December 13, 1912. *Continuation of investigations on fossil cycads.* (For previous reports see Year Books Nos. 2–4, 6–9, and 11.) $3,000

From the very beginning of these investigations of fossil cycads it has been evident that the widest study of Mesozoic floras was inseparably involved, and, as explained in previous reports, this wider study was successfully begun in the field in Mexico. It has, however, required some time for the Instituto Geologico de Mexico to bring out the results of the Mexican explorations, although the volume on the Oaxacan plants will soon appear, inasmuch as the entire series of fifty heliotyped plates has been printed and the accompanying text is in the printer's hands. This volume is entitled "La Flora Liásica

de la Mixteca Alta," and in it is described the first clear and well-represented Liassic flora from the Western Hemisphere. Meanwhile a study of the stratigraphic results obtained, together with a purely formal statement of the new facts of plant distribution brought to light, has already been published in the American Journal of Science for September.

The volume on the structure and taxonomy of the silicified cycads supplementary to publication 34, Carnegie Institution of Washington, and announced as well forward in preparation in the report of last year, is receiving careful attention. It is heartily desired to have this work well illustrated, and a portion of the more difficult illustration has been delayed in order to get the benefit of better equipment now at hand. It will be recalled that a large and remarkable additional series of thin sections has been made for these further studies. Specifically told, there is already prepared for this new volume a body of plate and text illustrations comparable to that of Publication 34, while most of the accompanying text has been written.

Work on the fossil cycads has thus occupied all of the present year, except a brief time diverted for an interesting study of the huge, ancient silicified seaweeds of Ozarkian time, with some brief notes on the accompanying oolites. These studies help to prove that the hitherto hypothetic "age of seaweeds" preceding the acrogens and older gymnosperms was a reality, and the results have been brought into form for early publication.

One of the most definite as well as significant accomplishments of the year has been the completion of a most excellent and usable private laboratory with space and convenience for work not only far in advance of anything previously available, but fully adequate for the study and safe storage of new collections.

PHILOLOGY.

Hempl, George, Stanford University, California. Grant No. 629, allotted December 14, 1909. *Researches on the origin and nature of Runic writing and on the Etruscan language.* (For previous report see Year Book No. 10.) $1,000

The year 1912 was devoted chiefly to the deciphering of hitherto unread Mediterranean scripts, and unexpectedly rich results were obtained.

(1) The resumption of the study of "Old Sabellic," begun in 1908, resulted in the definite determination of its character as an Italic dialect of the *p*-type, that is, of the group represented by Oscan and Umbrian.

(2) Success in reading the unique Siculian inscription on the wine decanter from Centuripæ (Kuhn's Zeitschrift, v. 35, p. 214) showed

the dialect to be intermediate between Latin and early Etruscan. This substantiates Freeman's prophecy that the speech of the Siculians, who came from four towns encircling Rome on the east, would turn out to be "Latin, or something which did not differ more widely from Latin than one dialect of Greek differed from another."

(3) The decipherment of the Lydian inscriptions, found by the Americans at Sardis in the summer of 1910 (American Journal of Archæology, 1911, v. 15, p. 149), proved Lydian to be an Indo-European language of the European branch.

(4) Success in reading numerous Lycian inscriptions revealed an Indo-European language which, like Lydian, shows close affinity both to Hellenic and to Italic speech.

(5) The decipherment of numerous Hittite pictographic inscriptions proved the language to be Greek of the type known to us as Attic. The writing turned out to be, not ideographic, as hitherto assumed, but iconomatic. The native name of the country is *Qteria* in the earlier texts, *Pteria* in the later; for many of the inscriptions were cut before *q* had changed to the π, τ, κ of the Greek hitherto known.

(6) The fact was thus established that the Hittites, as well as the Minoans (Year Book No. 10, page 232), were Greeks of that same Javonian stock that peopled Attica. We see that the four great civilizations, Minoan, Hittite, Attic, and Ionic, which form the foundation of European civilization, were all inspired by the genius of the same Greek strain. A comparison of the Greek features and posture of the gods carved on the rocky walls of Pteria with the Semitic cast of the sculptures found in the eastern portion of the Hittite empire makes clear the mixture of Greek and foreign blood in the border lands.

(7) These discoveries led to the recognition of the origins and congeners of various mythological personages. For example, the fact was established that Theseus and the Marathonian bull, as also Theseus and the Cretan minotaur, are resolutions of the old bull-god Tesup into a bull and the hero who slew him. That is, *Tesup*, *Tisup*, *Tisepo*, *Teisbas* (= *Theispos*, from *Thesippos*), the god of the Hittites and their Doric neighbors, was no other than *Thesippos*, the full form of *Theseus*, the national hero of Attica.

(8) Success in reading the non-Assyrian cuneiform texts found at Tell el Amarna in Egypt showed these to be Doric, and not Hittite, as generally supposed. The longer text is a letter from Tarqondōrous, king of Arzama (hitherto incorrectly transliterated Arzawa), to Amenophis III († about 1380 B. C.), arranging for the safe conduct of the daughter of the Egyptian king to the court of Arzama. The so-called shorter letter turned out to be no letter at all, but a song of praise in honor of Lappæus, or Lappaios (cuneiform *lab-ba-ia*,

la-ap-a-ya), the Greek chieftain often mentioned in the Assyrian letters found at Tell el Amarna. The song commemorates an expedition that Lappæus made against Qatra (cuneiform *chat-ra-a*), the Old-Doric form of Qteria, whose inhabitants are called 'Ιαϝενες (cuneiform *I-ia-u-e-ni*), as the people of Attica were called 'Ια(ϝ)ονες by Homer.

(9) These results led to the identification of Arzama and of Metan, later Mitan-i. Various considerations had led to the association or paralleling of Metan and Arzama, and to the location of them in upper Mesopotamia. These theories were corrected and made more specific. *Arzama* is the Old-Doric form of **Arzamia/Arzabia* (cuneiform *ar-za-bi-ia*), the name that later appears as *Arsamea*. This town lay on the Euphrates, due west of Amida, and just about where other considerations had led Winckler to locate Arzama. In classical times, Amida was the capital of the district called *Arzan-ene*, and was surrounded by a very galaxy of related names — *Arsamosata, Arsan-ias, Arsin-ia, Arzen*, etc. Compare Persian names like *Arsame, Arsames, Arsamos, Arsanos, Arsania*, etc. *Metan* (= *Meda-n*, originally a locative with postpositive 'εν) is identical with *A-mida* (originally a locative with prepositive 'α, the weak form of 'εν — just as German *Meppental* comes from older *im Eppental*). But *Μηδᾶ*, is the Old-Doric form of *Μηδία*, compare *Qατρᾶ* and *'Αρζαμᾶ*, the Old-Doric forms of *Qτερία* and *'Αρζαμία*. As the Doric accent was one mora to the right of the Attic, the unaccented ι was reduced or entirely lost. But *Μηδία*, with η for the α of Old Persian *Mada*, betrays Javonian phonology.

These philological data reveal the following historical facts: (1) that the Medes dwelt in upper Mesopotamia before they crossed Mount Taurus and descended into the Media of history; (2) that they left their old seats and the name of their capital to oncoming Javonian tribes; and (3) that these Javonians were succeeded by Dorians. We thus find Dorians in a new role, among the foremost of those who led the great prehistoric migration of men of Greek blood. We see that the ancient Greek world was a great deal larger, that Greek civilization was much older and more diversified, and that Greek speech broke up into dialects at a far earlier period than has hitherto been supposed.

(10) The continuation of the study of Minoan writing brought overwhelming evidence of the correctness of the view that the Greek alphabet represents the final stage of the development of Minoan iconomatic writing into syllabic writing and, later, pen-alphabetic writing. For example, in Minoan iconomatic writing, the figure of a Mediterranean plow , usually set erect so as to take up less room, is the regular sign for the vowel Λ, later A, the initial sound of *ἄροτρον*, the Greek word for "plow."

The rapidity with which these studies succeeded one another has prevented publication; but preliminary reports on Etruscan, Lydian, Lycian, Hittite, Minoan, and Old Doric are nearly ready for press.

Loew, E. A., Oxford, England. Grant No. 856, allotted December 13, 1912. *Continuation and completion of researches and publication of the "Scriptura Beneventana."* (For previous reports see Year Books Nos. 9–11.) $1,800

With a view to publishing—if the results warranted—a study of the early minuscule writing of the school of Würzburg, I investigated during the first quarter of 1913 the Latin MSS. from Würzburg which lie in the Bodleian. The researches are to be continued in Würzburg itself, which still possesses many of its ancient MSS. As the first fruit of these studies, I have prepared a paper on "The Oldest Catalogue of Würzburg MSS." This eighth century catalogue has given me the conviction that the unique Graeco-Latin MSS. of the Acts of the Apostles, which scholars agree is the very volume used by the Venerable Bede for his commentary on the Acts, had formed part of the ancient Würzburg library. As there was a suggestion that I be asked to write the preface to a facsimile edition of this MS., I began a minute study of it. Previously I had made a study of another very important Græco-Latin biblical MS., namely, the Codex Bezæ of Cambridge. I had the honor to submit the result of my investigations in a lecture at the University of Oxford, and a résumé of them has been published in the Journal of Theological Studies (XIV, 385–389). The subject deserves full treatment, and if accompanied by facsimiles will, I believe, be a contribution to the history of provincial Latin palæography.

Much of my time and attention has been devoted to seeing the "Beneventan Script" through the press. Owing to the unusual character of the text and other unforeseen difficulties, the printing has taken longer than was anticipated. So far only half of the book has been set up, but it is fully expected that this book will be issued before the year is over.

Most of my work has been done in the Bodleian at Oxford, where the facilities for such research are quite extraordinary, and where I have enjoyed great courtesy and helpfulness. I wish here to express my sense of obligation to Bodley's librarian and his assistants. My work has also taken me to Cambridge (University Library), London (British Museum), and Paris (Bibliothéque Nationale). In February three lectures were given at Oxford: (1) The dating and placing of Latin MSS.; (2) Bilingual MSS.; (3) The Codex Bezæ. In April a paper was read before the International Historical Congress held in London. The contributions to periodicals are listed in the Bibliography (p. 52.)

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. Grant No. 857, allotted December 13, 1912. *Study of the application of displacement interferometry.* (For previous reports see Year Books Nos. 4, 5, 7–11.) $500

Professor Barus is at present engaged in collating the data of a report containing a variety of investigations made at widely different times, but in all of which the displacement interferometer was used as a basis of measurement. It is thus a continuation of the work in Carnegie Institution of Washington publication No. 149.

In the first chapter, the distance apart of the doublet interference patterns, obtained with plates of doubly-refracting crystals, is used for computing the corresponding ordinary and extraordinary indices of refraction of these crystals in the case of light traveling through them in different directions. As quartz gives particularly beautiful and well-placed images, measurements were made in greatest number by means of it, though other bodies are also studied. It is an essential feature of the method that the center of ellipses is never lost, but may be brought back into coincidence with the fiducial sodium line of the spectrum by the proportionate displacement of the mirror on the micrometer. Hence plates of glass or crystal of any thickness, or indeed, columns of any length, are available for measurement. These wide limits of application are peculiarly favorable to certain accurate measurements. For instance, if a glass column 1 meter long is inserted, and the micrometer reads to but 0.5×10^{4} centimeter, $\mu-1$ (where μ is the index of refraction) would be measurable to one part in a million. The method should, therefore, be useful to answer certain questions in refraction.

The second chapter contains a number of miscellaneous measurements made on the displacement interferometer, or bearing upon it. Thus the ease with which it lends itself to the comparison of screws of any length is illustrated by many trials; a simple type of long screw micrometer is designed and investigated; a method for the measurement of very small increments of angle, consisting essentially in mounting two small mirrors in parallel and symmetrically to the axis, is tested; advantages in obtaining elliptic interferences when the reciprocating opaque mirrors are concave are discussed, etc. Furthermore, the availability of the interferometer in measuring certain acoustic displacements, such as occur in the Dvorak and Mayer experiments and telephone plates, is investigated. It is then shown that an induction balance of a peculiar kind may be constructed by replacing the opaque mirrors of the interferometer by mirrors attached to the synchronized and reciprocating plates of

modified telephones. If, for instance, one of these mirrors vibrates synchronously with the other towards and away from it, the ellipses remain in the field without displacement; if, however, the mirrors move in the same direction, the ellipses necessarily vanish. Hence, if there is a gradually increasing retardation in the electric circuit of one telephone only, the ellipses will alternately appear and vanish for identical intervals of retardation. The experiments attest the feasibility of so mounting the telephone mirrors on the interferometer that the balance may be realized. Finally, an attempt is made to study double refraction resulting from dielectric polarization both in solids and in liquids by the above method, while in allied sections the prismatic spectrum is studied on a Rowland spectrometer and certain peculiar results are shown in the resolution of interference fringes resembling the elliptic type.

The interferometry of highly exhausted air carrying electric current is briefly treated in the next chapter. The adjustment used is that originally proposed by Mach, in which the rays do not retrace their path but move along the sides of a parallelogram. The long exhaustion tube carrying current is placed in one of these sides, the light passing from end to end, and the effect of presence and absence of current on the interference pattern is determined. Thus far the exhaustions available were insufficient, so that the experiment in its final developments will be resumed at some time in the future. It is worth an inquiry to ascertain whether the motion of the cathode rays in a given direction may not produce some preponderating modification of the properties of the ether in that direction.

Chapter IV deals with the refraction of air at high temperatures investigated by the displacement interferometer (provided with water circulation) by comparing the refraction of a vacuum and of a plenum of air at each given temperature. As the system is not very sensitive to pressure, very perfect exhaustion is superfluous, but the need of sealed apparatus makes the experiments difficult at high temperatures. This chapter is but a beginning of experiments of this kind, which are naturally very difficult. It is curious that the refraction of Bunsen flame through which a beam of light passes symmetrically may be approximately found by this means.

Finally, in Chapter V the displacement interferometer is applied to the electrometer. A large number of forms of the instrument are designed and the results of each tested in detail. All of these are comprehended by the closed cylindric electrometer, in which a closed cylindrical charged needle is capable of displacement along the axis of a closed cylinder, consisting of two symmetrically insulated halves, oppositely charged. The suspension of the needle is of the pendulum type. If the ends of each cylinder are removed the instrument

reduces to the cylindrical pattern, in which the movable cylinder may be within or without the fixed cylinder. If the cylindrical mantle is removed the instrument is of the disk form, the simplest case of which is the absolute electrometer. All of these instruments may, with less sensitiveness, be used idiostatically. None of them, however, is exceptionally sensitive, the disk form (which is most sensitive and at the same time most treacherous) being characterized by a displacement of about 10^{-3} centimeter per volt, in favorable cases. Far greater sensitiveness is therefore secured by adapting the device of two small light parallel mirrors for the measurement of angle (as referred to above) to the needle of the quadrant electrometer. When this is properly done, an instrument capable of measuring 10 to 20 millionths of a volt per vanishing interference ring may be constructed, provided a satisfactory environment is at hand. The chapter also contains a great variety of experiments with each of these forms of apparatus.

Hayford, John F., Northwestern University, Evanston, Illinois. Grant No. 776, allotted December 15, 1911. *Investigation of the laws of evaporation and stream flow.* $2,000

The general plan of the investigation of evaporation is to consider each of the Great Lakes in turn as an evaporation pan, to evaluate the income, outgo (other than evaporation), and change of content of the lake, day by day, as accurately as possible, and from these evaluations to determine the daily evaporation and its relation to meteorological conditions. When sufficient progress has been made in the study of evaporation it is proposed to apply the knowledge thus gained to the investigation of the laws of stream flow in the United States. The progress made to date in the evaporation investigation has been satisfactory. Various difficulties have been encountered and overcome. No insuperable difficulties have appeared. It would be premature yet to report in detail the items of progress made or to estimate the degree of success that will probably be attained in the investigation. No attempt has thus far been made to study stream flow, as that portion of the study is intended to be based on more information in regard to evaporation than is now available.

Howe, Henry M., Columbia University, New York, N. Y. Grant No. 877, allotted March 21, 1913. *Study of the life history of the constituents of carbon steel, etc.* (For previous reports see Year Books Nos. 6–11.) $500

The upper limit of the transformation range of the iron-carbon alloys has been determined in a series of 19 steels varying in carbon content from 0.03 per cent to 1.43 per cent, and in special cases varying also in manganese content and in phosphorus content, by

noting the temperature (Ar3) at which the precipitation of pro-eutectoid ferrite starts in cooling down and that (Ac3) at which its reabsorption completes itself in heating up. The results of the 12 most important prior determinations of this upper limit have been discussed, and the formulæ

$$T^\circ = 917^\circ - 306 \times C \qquad \text{and} \qquad T^\circ = 820^\circ - 105.5 \times C$$

have been reached, in which T° = the temperature of this limit in degrees centigrade and C = the percentage of carbon. The results reached with the 19 steels noted above agree closely with this limit. Of the 12 prior sets of determinations, all but 3 harmonize tolerably with it. The 7 most important prior determinations of the lower limit of the transformation range have been discussed, and the temperature 723° found the most probable. But the existing data are such that these results should be taken as only provisional. The influence of manganese on the temperature of the transformation range has been studied. The data indicate, though not conclusively, that manganese lowers the Ar points, *i. e.*, those noted in falling temperature at the rate of from 25° to 50° per 1 per cent of that metal; that it has but slight effect on the Ac points, *i. e.*, those observed in rising temperature; and that it probably lowers the Ae points or those corresponding to equilibrium, by an amount so small that it is masked by the undercooling.

Starting from these determinations of the temperature of the transformation range, very many experiments have been made to determine the influence of the process of "grain refining," or cooling rapidly from the upper limit of that range and then reheating to a predetermined temperature below that range, and more particularly to learn the influence of specific deviations of the quenching temperature from that limit. These experiments are still in progress.

Many experiments have been made to determine the laws of "divorcing annealing," called also the "segregation" and the "disentangling" of the constituents of pearlite, the eutectoid of this series of alloys, and to learn the influence of this divorcing on the more useful properties. The results, which are still under discussion, show that this divorcing lowers the yield point, and in the case of eutectoid and hyper-eutectoid steels lowers it very greatly, and that (at least in certain steels) it lessens the impact-resistance as usually determined by noting the energy absorbed in the rupture of a notched test-piece by transverse impact.

The apparently excessive quantity of pro-eutectoid cementite found at certain stages of the transformation of hyper-eutectoid steels, as pointed out in the last report, seems referable at least in part to undercooling.

Nichols, E. L., Cornell University, Ithaca, New York. Grant No. 840, allotted December 13, 1912. *Systematic study of the properties of matter through a wide range of temperatures.* (For previous reports see Year Books Nos. 4–11.) $3,000

(1) *Fluorescence and phosphorescence:*

The year's work on the spectra of the uranyl salts has been chiefly devoted to the detailed study of the very complicated groups of series of narrow bands existing in the fluorescence and absorption spectra of these salts at the temperature of liquid air. In addition to the series described by Becquerel and Onnes, we find numerous other series of nearly if not exactly constant frequency differences and having nearly the same intervals for the various salts. Many photographs of these spectra have been measured and charted and the results are now being discussed and compared to determine in how far the various salts have series in common and to establish if possible the effect of molecular weight and of the presence of water of crystallization upon the location and character of the bands. Besides this study of the spectra of these salts in the solid form a preliminary investigation has been made of the fluorescence spectra of their aqueous and alcoholic solutions, frozen and excited at various temperatures down to 180° C. An account of the many striking and significant modifications which these spectra undergo when the concentration and the temperature of excitation are varied will be published in a note now in preparation. Mr. H. L. Howes, who has assisted us throughout the experiments above described, has in hand a detailed investigation of the spectra of these solutions.

Dr. G. E. Thompson has completed the study, in which he has been engaged for the past three years, of the electro-motive forces developed in certain cells with electrolytes consisting of alcoholic solutions of rhodamin and other fluorescent substances when exposed to light. He finds that while the effect is selective, as regards the wave-length of the effective rays, the exciting band apparently coincides with neither the fluorescence band nor the absorption band of the solution, but has its maximum further towards the violet. While all wavelengths capable of producing electromotive force also excite fluorescence, and while the effect has been observed only with fluorescing solutions, there does not appear to be any very intimate connection between the two phenomena.

Dr. E. H. Kennard has been engaged in an investigation of the law of the decay of phosphorescence of certain organic substances when excited at the temperature of liquid air. It was thought that the curves of decay hitherto studied might owe their complex character to the lack of homogeneity and that substances which are physically homogeneous might show a simpler form. This has been found to be true with the materials thus far examined, *i. e.*, kerosene oil and par-

affin, the decay curves being of such a character that the reciprocal of the square root of the intensity is a linear function of the time as long as the intensity is great enough for accurate measurement. Toward the end of the period of decay there seems, however, to be a marked deviation from the simple linear relation. This part of the curve is being studied further. In measuring intensities Dr. Kennard has used a photo-electric cell and has found this method sensitive and reliable.

Dr. Frances G. Wick is continuing her spectrophotometric measurements of the absorption, fluorescence, and surface color of certain double platino-cyanides. The results, which can not well be briefly stated, are in large part ready for publication.

Mr. T. B. Brown is continuing the work of the late Dr. Veasey on kathodo-luminescence under varying conditions of excitation, as regards pressure in the tube, applied electromotive force, and current.

Mr. H. E. Howe, after a year's absence, has resumed his photographic measurements of the fluorescence and absorption of a group of organic compounds related to fluorescein and eosin.

(2) *The effect of temperature on the properties of substances:*

Dr. H. D. Ayres has completed measurements of the indices of refraction of oxygen, nitrogen, and hydrogen between +20° C. and −180° C. and of carbon dioxide between +20° C. and −60° C. by an interference method, the apparatus used being a modification of that employed by Dorsey (Physical Review, vol. xxv, p. 88) in the study of coefficients of expansion. Needed data concerning the effect of temperature on this physical constant were obtained and the accuracy of Gladstone and Dale's law over a greatly extended range of temperatures was established (see Physical Review, September 1913).

Mr. Anders K. Ångström has begun the study of the reflection bands of various substances in the infra-red, for which purpose a Nichols radiometer and reflecting spectrometer were used. This method has been found to give far more detail, in regions where the absorption is great, than it is possible to obtain by measurements of the transmitted radiation. It is also well adapted for the study of the effects of temperature on absorption and it is proposed to extend the experiments to substances cooled to the temperature of liquid air.

Mr. C. C. Bidwell has made a series of measurements of the departure of metal surfaces, especially of iron, silver, copper, gold, and platinum, from Wien's law of radiation. For this purpose he has devised a new thermo-element, which was described at the meeting of the American Physical Society in April 1913 (see Physical Review, vol. I, series II, p. 482). This couple, consisting of graphite and of arc-light carbons previously subjected to a special heat treatment, extends the possibility of the direct measurement of temperatures to about 2200° C. Having calibrated this thermo-couple, under con-

ditions insuring radiation corresponding to that of an ideal black body, by observations with an optical pyrometer, the actual temperature of the metal, electrically heated, as indicated by the thermocouple, is compared with the apparent temperature as given by the same optical pyrometer, and the departure of the metal from the laws for black bodies is noted both in the solid and the molten state. By allowing the molten mass to undercool, the radiation from molten and solid metals at the same temperatures has been determined through a considerable range below the normal point of solidification. Mr. Bidwell has also in hand preparations for an extended and systematic investigation of the electrical properties of the metallic oxides at high temperatures. This work will be a continuation and extension of the measurements of the electrical resistance between 400° C. and 1100° C. of certain of these oxides recently made by Dr. A. A. Somerville (see Physical Review, vol. I, series II, p. 243, and previous papers).

Professor R. C. Gibbs and Mr. K. S. Gibson are continuing their spectrophotometric observations of the effect of temperature, between 400° C. and −180° C., upon the absorption of colored glasses, of which mention has been made in previous reports.

Professor J. S. Shearer and Mr. C. C. Murdock have completed the preliminary work in their investigation of the specific heats of gases at low temperatures and are ready for the final measurements.

PHYSIOLOGY.

Reichert, E. T., University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 858, allotted December 13, 1912. *Study of differentiation and specificity of corresponding vital substances.* (For previous reports see Year Books Nos. 9–11.) $1,500

This research is a continuation of those reported as publications 116 and 173 of the Carnegie Institution of Washington and is with especial reference to the effects of hybridization upon corresponding vital substances, especially starches. Since the submission of the report of the investigations of stereoisomers embodied in publication No. 173 (April 1912) the methods pursued in the differentiation of starches from different sources have been considerably extended and improved. Variables which may under certain conditions give rise to fallacious results have been to such an extent eliminated that the records now obtained are as closely in accord as those found in the determinations of melting-points and in ordinary titration procedures, and hence are practically accurate. The results thus far recorded in the present research are in support of the findings in the preceding researches to the effect that complex organic metabolites, such as starch, are specifically modified in relation to genera, species, varieties, etc., and hence constitute not only a specific means of

differentiation, but also lead us close to the understanding of the mechanisms of protoplasm, to which we must look for the explanations of the phenomena of living matter.

POLITICAL SCIENCE.

Rowe, L. S., University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 633, allotted Dec. 14, 1909. *Study of federal system of Mexico.* (For previous reports see Year Books Nos. 8–11.) $1,500

In 1910, under a grant from the Carnegie Institution of Washington, Dr. Rowe began the study of the Mexican Federal system. In 1911 and 1912 he returned to Mexico for the purpose of continuing the investigation and collecting additional material. These trips were made without any further grants from the Institution. For the concluding chapter, "Constitutional Guarantees in the Mexican Political System," additional material must be secured. The manuscript will probably be completed during the coming winter.

PSYCHOLOGY.

Franz, S. I., Government Hospital for the Insane, Washington, District of Columbia. Grant No. 80, allotted March 13, 1903. *Investigation of the functions of the cerebrum.* (For previous reports see Year Books Nos. 4–10.) $1,000

During the two years, September 1, 1911, to August 31, 1913, the publication of the results of researches on the functions of the occipital lobes were completed; work on the motor functions of the occipital lobes and on the motor functions of the precentral cortex is still in progress.

ZOOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. Grant No. 841, allotted December 13, 1912. *Continuation of experimental study of heredity in small mammals.* (For previous reports see Year Books Nos. 3–11.) $1,000

During the past year several investigations of heredity, with which the writer has been for some time occupied, have been completed or brought to a point where definite conclusions could be drawn from them.

The selection experiments with rats, in which Dr. John C. Phillips has collaborated, have reached a point which warrants full publication. These experiments have extended over a period of 7 years, in the course of which over 20,000 rats have been raised and studied.

During this period the details of this work have received personal attention from one or both of us. The results obtained, we believe, have an important bearing on the question of the efficacy of mass

selection, a question which has deservedly received much attention from biologists in the last 15 years. The tendency has been, largely on theoretical grounds, to discredit selection as an agency in evolution, in favor of mutation. Our results indicate that selection is in animal breeding a more important agency than mutation, partly because it is controllable and so its results are more certain, and partly because it may even determine the occurrence of mutations of a particular sort. We have recently presented for publication our full data.

Dr. Phillips and the writer have also prepared for publication further data on ovarian transplantation in guinea-pigs, which substantiate results previously obtained. In three cases, two of which were mentioned in Year Book No. 10, transplanted ovaries functioned in the production of living young which showed color characters borne by the animal which furnished the ovary but not by the animal which bore the young. These color characters were transmitted to later generations of offspring in the ordinary way and without observable modification.

Mr. C. C. Little's results from his studies of the inheritance of color in mice, which have been in progress for several years under the writer's direction, has recently appeared in Publication No. 179, illustrated with 5 colored plates. This same publication contains in a separate paper the writer's full data concerning the production through crossing and the fixation as a racial character of the agouti coat-pattern of guinea-pigs, the general results of which were briefly announced several years ago.

Dr. E. C. MacDowell's studies of size inheritance in rabbits have been submitted for publication. The animals most recently reared in his experiments attained maturity several months ago, since which time his data have been undergoing statistical study and analysis. His results indicate that size inheritance in mammals, although it is correctly described as "blending or intermediate," is capable of explanation as a form of Mendelian inheritance involving many independent factors without the occurrence of dominance. This interpretation, however, presents no practical advantage and may have to be revised later. The important point in Dr. MacDowell's work is the careful determination of the facts, which are fully recorded in his paper. Dr. MacDowell, after two years of service as my assistant, became a year ago instructor in zoology in Dartmouth College, and is now organizing work in animal genetics at Yale University.

Dr. John Detlefsen, formerly my assistant in charge of certain experiments with guinea-pig hybrids, became a year ago assistant professor of genetics at the University of Illinois. During the past year he has, with the consent of the authorities at that institution, devoted considerable time to the study of material accumulated from

those experiments. It is hoped that his results may shortly be ready for publication in full. A preliminary paper has already appeared (see Bibliography, p. 49). His results are concerned principally with a study of interspecific sterility and its gradual replacement with complete fertility in later generations of the hybrids between the guinea-pig and *Cavia rufescens*.

Among the more recently started lines of experiment which are now in progress and are occupying the greater part of my attention should be mentioned those with guinea-pigs obtained in Peru two years ago. The small wild species obtained at Arequipa breeds readily in captivity throughout the year, producing litters of from 1 to 3 young. Two generations reared in the laboratory show no deviation from the typical form of the wild ancestors. When this species is crossed with the domesticated guinea-pig, which is about twice its size, hybrids are obtained which are of about the size of guinea-pigs but show the color of the wild species, with intensification of the colors in most cases, and invariably so when an intensely colored race of guinea-pig is used in making the cross. The next generation of hybrids (F_2) produces a great number of color varieties, in full accord with the Mendelian expectation. It is too early to say what the adult size of the hybrids in this generation will be. The complete fertility of the F_1 hybrids is noteworthy as indicating no specific distinctness between the wild form and the guinea-pig. This is in marked contrast to the behavior of the hybrids with *Cavia rufescens* already referred to. It supports the idea that the wild species still occurring among the Andes is the form from which the domesticated guinea-pig is descended.

A domesticated and a (possibly) feral stock of guinea-pigs, which were obtained in Peru two years ago, have yielded two series of novel color varieties entirely unknown hitherto, so far as I can learn, in North America and Europe. A preliminary description of these will shortly be published. My colleague, Mr. C. T. Brues, of the department of entomology of the Bussey Institution, recently returned from Peru, whither he went to study insect carriers of tropical diseases. He has kindly brought back 8 guinea-pigs from a third locality in Peru, among which occurs one of the variations which had cropped out in the stocks obtained in 1911. To study more intensively these novel variations in guinea-pigs and also certain problems of inheritance in rabbits which have recently taken on new aspects, we are enlarging our accommodations for small mammals and equipping them with a hot-water heating apparatus, to reduce as much as possible the losses of animals in cold weather. The expense of these changes will be borne by the Bussey Institution.

The particular objects which the writer has in mind to accomplish in future work are (1) a further study of heredity in the guinea-pig

through experimental breeding of the varieties which he has had under observation for the past 13 years and crosses of these varieties with the varieties and species obtained from Peru and to be obtained from other parts of South America. For this latter purpose he has in mind an early expedition to regions of Brazil, Argentina, and Bolivia, where several distinct species of cavy are reported to occur, but which it seems quite impossible to obtain except by personal efforts. (2) A second objective point is further study of selection in relation to mutation and the possible control of mutation through selection. For this rats seem to be especially favorable material and it is proposed to utilize the stocks already in hand. (3) A third object for intensive study is the interrelations and modifiability of certain color patterns in rabbits, some of which are dominant, others recessive in crosses. One phase of these questions the writer has been studying for the past three years in collaboration with Dr. P. B. Hadley, of the Rhode Island Agricultural Experiment Station. Two or three more years of work will be required to attain our objective point.

Naples Zoölogical Station, Naples, Italy. Grant No. 842, allotted December 13, 1912. *Maintenance of two tables for American biologists.* (For previous reports see Year Books Nos. 2–11.) $1,000

The two Carnegie Institution study tables were, during the last term, occupied by Professor Howard S. Reed, plant pathologist of the Virginia Agricultural Experiment Station, and Professor Ulric Dahlgren, of Princeton University.

Professor Reed worked on the permeability of the living cell. After some preparatory work on *Bornetia* and *Griffithia,* he concentrated his researches upon *Valonia,* and studied the amount of ammonium salts which enter the living cell under normal conditions and also in the presence of different substances (vanilline, cumarine, heliotropine, etc.).

Professor Dahlgren was occupied with cytological researches on the cells of the electric organ of torpedo, of which he found abundance of material during his whole stay at the zoölogical station. He was also interested in the phenomena of luminescence in various marine animals.

Riddle, Oscar, University of Chicago, Chicago, Illinois. Grant No. 845, allotted December 13, 1912. *Preparation for publication of the manuscripts of the late Dr. C. O. Whitman, provision for care and maintenance of the Whitman pigeon collection, and continuation of investigations necessary for completion of Dr. Whitman's manuscripts.* (For previous report see Year Book No. 11.) $4,400

Considerable preliminary work has been done with Professor Whitman's records and manuscripts bearing on orthogenesis, the chief subject of his unpublished studies. Much work will be required

to bring all the manuscripts, records, and hundreds of illustrations together in publishable form. The manuscripts and data on "voice" and on "behavior" have been placed for compilation in the hands of persons specially familiar with these subjects. The manuscripts on the "shifting of dominance of sex" are nearly ready for publication, but the inaccessibility of certain materials has delayed completion.

Confirmation has been obtained of the indications of the previous year's work, to the effect that females of two grades of femininity result from reciprocal crosses of *Turtur orientalis* and *T. alba*. Moreover, two further facts have appeared in behavior studies on the females of this sex-controlled material: First, females hatched from eggs ovulated in or near the male-producing season (spring and early summer) are more masculine than their full sisters hatched from later eggs of the season (in what has been shown to be the female-producing season). Second, when two females are hatched from the same clutch, it has been shown that in about three times in four the female from the first egg of the clutch is the more masculine of the two, and (in most pairs) will invariably take the part of a male in copulating with such female from the second egg of the clutch. The results strongly indicate that the hereditary basis of sex (and therefore, probably all characters) is a quantitative, graduated thing; not qualitative and alternative, as rather generally believed.

Chemical and energy measurements on the male and female producing ova of pigeons has this year been continued on 26 birds. In addition, the total yearly output (on a basis of weight) of the ovaries of 41 birds is being followed throughout the year. A volume dealing with these data will probably be made ready for publication next year.

Work on the storage metabolism of ova has progressed so far as already to suggest certain chemical procedures which may render practical, and greatly extend, the matter of experimental sex control as it was obtained by Professor Whitman. Some preliminary experiments to test these indicated methods of sex determination have been undertaken, but it is as yet too early to report upon the results.

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